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THE AUTHORS OF THE SEVERAL PAPERS ARE INDIVIDUALLY RESPONSIBLE FOR THE SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE STATEMENTS MADE THEREIN.

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PART II.

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[Proc. Roy. Soc. Victoria. 51 (N.S.), Pt. I., 1938.]

Art. I.—*Studies on the Australian Clavariaceae.*

Part I.

By STELLA G. M. FAWCETT.

[Read 16th December, 1937; issued separately, 23rd January, 1939.]

The plants comprising the family Clavariaceae are commonly known as coral-fungi, taking their name from the larger and more spectacular members, but there are many smaller plants included in the family, which bear no resemblance to coral, and which are more accurately described by the name *Clavaria* (L. clava, a club).

The family Clavariaceae at present includes the following genera: *Clavaria, Typhula, Pistillaria, Lachnocladium, Pterula* and *Physalacria*. (*Myxomycidium,* long held to be of this family, has been the subject of a paper by Linder (16) who places the genus in the Vuilleminiaceae. The issue is complicated, and will be discussed later, but it is necessary to say that at least two of the premises on which he based his assumption, have, by recent work on *Clavarias,* been shown to be false).

The family Clavariaceae has been fully described by Coker (7) who states that the hymenium is "more or les amphigenous."

In appearance and texture the family approaches the Thelephoraceae from which, in the past, its members were distinguished on grounds of texture and "a more or less amphigenous hymenium." Thus *Sparassis* was formerly included in the Clavariaceae.. Engler and Prantl (10) give the position of the hymenium in the Clavariaceae as amphigenous. Although, in describing the family, Rea (19), says that the hymenium is "more or less amphigenous.", there is nothing in the generic and specific descriptions of members of the family, to indicate that the hymenium is ever anything less than amphigenous. For instance, Rea states, p. 705, *Clavaria* "hymenium even, amphigenous," p. 720 *Typhula* "hymenium smooth, confined to the clavate portion of the receptacle," p. 722 *Pistillaria* "hymenium smooth, confined to the clavate portion of the receptacle," *Pterula* "hymenium smooth."

I have examined one species of *Pterula,* and the branches, although fine, were cylindrical, and the hymenium amphigenous. Rea (19) does not deal with *Lachnocladium*, but Coker (7), in defining the genus says, "hymenium covering the plant completely, except for the tomentose tips and sterile base."

Coker, in discussing *Physalacria,* states that the hymenium only occurs on the lower surface of the head. In Victorian plants, identified as *P. inflata*, the hymenium was found to cover completely the entire swollen part of the plant.

Thus there is strong evidence for the non-occurrence of dorsiventrality in the Clavariaceae, and I suggest that the amphigenous hymenium is characteristic of the family and serves to distinguish it from the Thelephoraceae.

At the present time the classification of the family is in a chaotic state, as the genera have been poorly defined and several of the definitive characters are of poor systematic value. For instance, differences in texture have been used to separate genera. The texture of a plant is difficult to define exactly, and although a number of plants in the family have indisputably tough, fleshy or waxy textures, difficulties arise when plants showing a texture intermediate between any two of these three are considered, and one finds all gradations between soft, fleshy, gelatinous and woody in this family.

In this account of the Clavariaceae, use has been made, as far as possible, of morphological features in the separation of genera and species.

Distribution and Habit of the Family.

The Clavariaceae is well distributed in temperate and tropical countries, and a few species occur in sub-arctic regions. While each area has a number of species which are peculiar to it, there are many such as *Clavaria botrytis* and *C. flava*, which are of world-wide occurrence. In temperate regions the fruiting periods are generally late autumn and early spring.

Although most members of the family appear to be unspecialized saprophytes, a large number grow only on decaying wood, and others require the decaying parts of specific plants for their growth. For instance *Pistillaria fulgida* Fr. (19) grows only on the dead stems of *Dipsacus pilosus* and *Helianthus tuberosus,* and a large group, including *C. gracilis* and *C. abietina,* will grow only on fallen leaves and twigs of Conifers.

There are a few parasites included in the family, chiefly species of *Typhula* e.g. *T. Itoana* Imai is a parasite on wheat and oats in Japan.

In spite of the apparently unspecialized food requirements of most of the family, attempts to grow them in culture have been unsuccessful, with one exception, *C. complanata* Clel., which grows well on 2 per cent. malt agar. It was thought that cultural characters might be of use in the classification of difficult species.

Tissue cultures were attempted with nine species of *Clavaria* on the following media: malt agar, honey agar, raisin agar; spores of the same nine species were sown on plates of the following media: malt agar, plain agar, sterile soil, honey agar, raisin agar, potato dextrose agar, sterile water, malt agar with lactic acid, and malt agar with sodium hydroxide. Freshly obtained and three months' old spores were used.

Varying temperatures had no effect. Cultures were incubated at 4°C., 23°C., and 30°C., and also at room temperature. In addition a suspension of spores *C. flava* in sterile water, was divided into six parts. Two parts were kept at room temperature, two parts were left in the open and the others were kept at 4°C. This preliminary treatment lasted for five weeks. Then one tube from each set of conditions was heated to 42°C. for ten minutes the others being kept as a control. After this treatment the six tubes were incubated at 30°C. Result: no germination in twenty-one days.

Keeping the cultures in complete darkness had no effect. Digestion experiments were also tried. Three malt agar plates were sown with spores of *C. corallino-rosacea,* and three more with spores of *C. fusiformis.* To the first plate of each kind 0.001 per cent. NaOH and trypsin was added, to the second 0.001 per cent. HCl. and pepsin, and the third plates were kept as controls. All were incubated at 35°C. for 21 days. No spores germinated.

Historical Survey.

Hitherto, accounts of the Australian Clavariaceae have been almost exclusively confined to the genus *Clavaria.* This is understandable as species of *Clavaria* are the most commonly seen. *C. Kalchbrenneri* was described by von Mueller (15) (not *C. Kalchbrenneri* Sacc.), and he sent many specimens to Cooke (8), who published these records together with descriptions of all the Australian species described before 1892. Since then McAlpine has described one species, *C. phyllophila* (17), and Rodway has listed a number of Tasmanian species. In " Records of Australian Fungi " (6), Cleland and Cheel discuss the occurrence and characters of several species recorded by Cooke. In 1931, Cleland (4) described eight new species, and, in a more recent publication (5) records sixteen species.

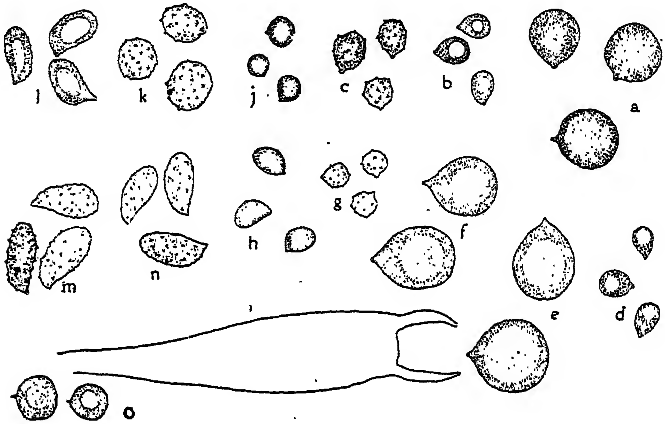
In 1932 McLennan (18) published an account of the common Victorian species of *Clavaria* to stimulate interest in them. Japanese work undertaken by Imai has some bearing on Australian studies in the group, as many species are common to both countries (11-14).

Genus **Clavaria** Vaill.

The most complete definition of the genus is that given by Coker (7). He says that the habit is " saprophytic, or in a few species saprophytically associated with algae." Since this description was published, one species, *C. Tochinaiana* Imai (11), has been described as a parasite of cabbage. Since the first description of the genus there have been many attempts to subdivide it. (For full discussion see Coker(7)). The classification devised by Fries, which has been in common use for many

years, has been amplified by Coker so that the genus is divided into eleven groups, which he considers are " of a validity at least equal to accepted genera of agarics and other families of fungi," but he states that " to distinguish sharply between such groups is, however, no easier than in most cases of splitting, and we are inclined to choose here a course that we should like to see much more generally followed, which is to let the old genera alone until it becomes a greater inconvenience to retain them than to separate them."

In this paper Coker's classification has been followed and groups 3, 4, 7, 8 and 9 of the genus are dealt with.



TEXT FIGURE 1.

Spores of the following species of *Clavaria*:—(*a*) *C. muscoides*. (*b*) *C. subtilis*. (*c*) *C. Kunzei* (from specimen at National Herbarium, Melbourne, identified by Cooke). (*d*) *C. cinnamonea* (type). (*e*) *C. cristata*. (*f*) *C. vinaceo-cervina* (part of co-type). (*g*) *C. Crocea*. (*h*) *C. umbrinella* and (*i*) basidium of *C. vinaceo-cervina* (part of co-type). Note the two large incurved sterigmata. Spores of: (*j*) *C. Bizzozeriana*. (*k*) *C. pyxidata* var. *asperospora* (type). (*l*) *C. gracilis*. (*m*) *C. crispula*. (*n*) *C. stricta*. (*o*) *C. Nymaniana*. Magnification × 1125.

GROUP 3.

CLAVARIA MUSCOIDES Fr. ex L. Flora Suecica (2nd ed.), p. 457, 1755.

Plate I., Figs. 1 and 2.

Clavaria fastigiata L. Flora Suecica (2nd ed.) p. 457, 1755.
Clavaria corniculata Schaeff. Fung. Bavar. pl. 173, 1763.
Clavaria pratensis Pers. Comm. p. 52 (183), 1797.
Clavaria furcata Pers. *Ibid.*, p. 52, 1797.
Clavaria vitellina Pk. Rept. N.Y. St. Mus., 43:24, (70), 1890 (not *C. similis* Boud. and Pat.).
Clavaria Peckii Sacc. Syll. Fung. 9–249, 1891 (not *C. Peckii* Sacc. and D. Sacc.).
Clavaria helveola var. *dispar*. Pers. Myc. Europ. 1:181, 1822.
Clavaria fellea Pk. Rept. N.Y. St. Mus., 51:292, 1898.
Clavaria muscoides var. *obtusata* Britz. Hymen. Sudb., Clavariei, fig. 45, 1879–97.
Clavaria straminea Cotton. Trans. Brit. Myc. Soc. 3, 265, pl. 11, fig. D, 1909–10.

Plants of moderate size, 5-8 cm. high, rarely simple, most often antlered or branched two or three or four times, growing in clusters of two or three separate plants, occasionally forming a large mass in which the individual plants are fused at the base, more or less rooting. Stem long or short, of the same diameter as the branches which are usually between 2 and 3 mm. in diameter, branching irregularly dichotomous, axils open and rounded, much flattened below, branches elongated, cylindrical, smooth and flexuous, tapering bluntly to form entire tips. Colour of young plants Light Orange Yellow, of mature plants Cinnamon Buff at the tips, shading to Clay Colour at the base.

Texture when young, moderately brittle, in age, rather tough. Flesh rather translucent but the outside layers i.e. the hymenial and sub-hymenial layers, are very opaque. Taste and smell slight, but acrid and unpleasant; in age, a strong odour of ammonia develops.

Spores white in mass, smooth, globose, with an abrupt minute apiculus 5.6-8μ. Basidia 4-spored, sterigmata curved, about 7-8μ long.

Coker describes the colour of *C. muscoides* as "varying from rather pale dull yellow to deep clear yellow or ochraceous yellow shading downward to darker brown." Mature plants found in Victoria are much browner than this. But Coker regards *C. straminea* Cotton as a synonym of *C. muscoides*. He states "no differences of any importance between *C. straminea* and *C. muscoides* appear from Cotton's description of the former. Simple plants of *C. muscoides* are not at all rare in Victoria, and could hardly be better described than by Cotton's diagnosis for *C. straminea*." The Australian plants are straw-coloured like *C. straminea*. Very yellow specimens have not been collected here.

Cooke records *C. muscoides* for Victoria and New South Wales, spores 6μ diam. in pastures.

GROUP 4.

CLAVARIA CRISTATA Fr. ex Holmsk. Rolland, Champ. T 103, no. 230.

Plate 1, Figs. 3-5; Plate 2, Fig. 1; Text fig. 1, e.f.i.

Clavaria coralloides L. (in part) Fl. Suecica, 2nd ed., p. 457, 1755.

Clavaria albida Schaeff. Fung. Bavar, p. 116, pl. 170, 1763.

Clavaria laciniata Schaeff. *Ibid.*, p. 122, pl. 291, 1770.

Clavaria cinerea Bull. Herb. Fr. p. 204, pl. 354, 1787.

Clavaria rugosa Bull. *Ibid.*, p. 206, pl. 448, fig. 2, 1789 (not *C. rugosa* sensu Sowerby Engl. Fung. pl. 235).

Clavaria elegans Bolton. Hist. Fungi Halifax, p. 115, pl. 115, 1789.

Clavaria amethystea Bull. Herb. Fr. p. 200, pl. 496, fig. 2, 1790.

Clavaria cristata Holmsk. Beata ruris I: 92, pl. 23, 1790 (p. 97, Pers. ed. 1797).

Clavaria fimbriata Pers. N. Mag. Bot (Romer's) p. 117, 1794.

Clavaria trichopus Pers. Comm. p. 50 (182) pl. 4, fig. 3, 1797.

Clavaria palmata Pers. *Ibid.*, p. 45 (177) 1797.
Clavaria fallax Pers. *Ibid.*, p. 48 (180) 1797 (not *C. palmata* Scop.).
Clavaria grisea Pers. Comm. p. 44 (176) 1797.
Clavaria grossa Pers. *Ibid.*, p. 50 (182) 1797.
Clavaria macropus Pers. (sense of Fries and Bresadola) Comm. p. 51 (183) pl. 1, fig. 2, 1797.
Clavaria fuliginea Pers. Myc. Europ. I, 166, 1822.
Clavaria alba Pers. *Ibid.*, 1, 161, 1822.
Clavaria cristata var. *curta* Junghuhn. Linnaea 5, 407, pl. 7, fig. 2*b*, 1830.
Clavaria afflata Jagg. (sense of Bresadola) Flora 19 (1), 231, 1836.
Clavaria cristata var. *flexuosa* Junghuhn. Linnaea 5, 407, pl. 7, fig. 2*a*, 1830.
Clavaria Krombholzii Fr. Epicr, p. 572, 1838.
Clavaria lilacina Fr. Hym. Eur. p. 667, 1874 (not *C. lilacina* Junghuhn).
Clavaria dichotoma Godey. in Gillet. Hym. Fr. p. 766, 1874.
Clavaria Schaefferi Sacc. Syll. Fung. 6, 693, 1888.
Clavaria sphaerospora E. & E. Journ. Mycol. 4, 62, 1888.
Clavaria sublilacina Karst. Finlands Basidsvampar p. 375, 1889.
Clavaria Favreae (Quel) Sacc. & Trav. Syll. Fung. 19, 231, 1910.
Clavaria Herveyi Pk. Rept. N.Y. St. Mus. 45, 84, 1892 (*rugosa* form).
Clavaria cinerea var. *gracilis* Rea. Trans. Brit. Myc. Soc. 6, 62, 1917.
Clavaria mutans Burt., Ann. Mo. Bot. Gard., 9, 31, pl. 6, fig. 41, 1922.
Clavaria histrix E. & E. Herbarium name.
Clavaria vinacceo cervina Clel. Trans. Roy. Soc. S.A., 1931.
Clavaria sub-rugosa Clel. *Ibid.*, p. 152-160.

Coker's description of *C. cristata* is as follows: "Remarkably variable in both form and colour. The typical form is whitish or pallid. Slender, narrow about 2-3 mm. thick below and 3-6 cm. high, long stalked with a few or several branches which are rather abruptly crested at the ends with small, pointed, more or less crowded branchlets; sometimes there is a single slender stalk with a dense crest at the tip, or there may be several stalks attached near the base and these may branch near the middle. Other forms besides the typical are included in the following notes. At times none of the branches is crested or some may be crested and others not; also the stem may be much flattened and expanded upwards, with a few irregular flat branches, or with no branches but rugose-wrinkled or knobbed. The tip is sometimes flattened and expanded like an antler, and in less complex forms the plants are apt to be somewhat enlarged and flattened upwards. Colour white at base and usually light-grayish flesh colour elsewhere, except the tips which are creamy white when young, then becoming coloured more like the branches and easily blackening after maturity. The colour varies from dull or creamy white to lavender gray (or with a tint of this colour with

tan), or smoky lavender pale to deep mouse gray, ash colour, drab or dull yellow, with all admixtures of these colours, surface even below, more or less channelled or wrinkled upwards. Flesh dry, toughish, not brittle, bending on itself without a complete break, creamy white, softer inside, and usually with one or two small uneven cavities in centre from separation of the fibres. odour almost none, taste mild, not very pleasant, bitterish, musty, at times a little like that of *Agaricus campestris.*

Spores when fresh, pure white, smooth, regular, sub-spherical to short elliptic, 5.2-7.4 x 7-9.2μ, after standing for some time they become yellowish and often irregular by collapsing. Basidia 2-spored in all forms, the long stout sterigmata usually curved inward. Hymenium thick 110-165μ and with many spores irregularly embedded through most of its area, indicating a great increase in thickness by irregular proliferation."

" Edible and of the best quality." (McIlvaine).

" The great variability of this plant has led to many names and much confusion. The large smooth sub-spherical spores, pliable texture and blackening tips are the surest guides." (Coker.)

Cotton and Wakefield only recognized *C. cristata, C. cinerea,* and *C. rugosa,* and say that it is possible that *C. cristata* may be a form of *C. rugosa.* Rea recognizes the following species and varieties :—

Clavaria coralloides (Linn.) Fr. (?).
Clavaria cristata (Holmsk) Fr.
Clavaria cinerea (Bull.) Fr.
Clavaria cinerea var. *gracilis* Rea.
Clavaria rugosa (Bull.) Fr.
Clavaria rugosa var. *fuliginea* (Pers.) Fr.
Clavaria rugosa var. *macrospora* Britz.
Clavaria grossa Pers. Quel. (?=*C. Krombholzii*).
Clavaria crassa Britzl. (?=*C. rugosa*).
Clavaria Krombholzii Fr.
Clavaria grisea (Pers.) Fr.

Coker has collected a great number of spore measurements and other details, and concludes that all the forms listed as synonyms can be included in the species *C. cristata.*

Coker states: " We have been unable to find any differences either in gross character or in microscopic detail, of sufficient importance to enable us to distinguish species within the group." Romell stated that he could see no distinct limit between *C. cristata, C. cinerea,* and *C. rugosa.*

The commonest variety in Victoria appears to be the *cinerea* form, which is often found much incrassated and proliferated. I have not seen any large, much branched *cristata* forms, but small specimens up to 1½ inches in height are common for the greater part of the year.

Cleland (4) has described a South Australian plant as *C. sub-rugosa.* It is "white, becoming slightly dingy, Pallid Greyish White or near Cartridge Buff. Spores spherical 5.6-7.5μ."

The spores of the South Australian plant are smaller than those given by Cotton and Wakefield for *C. rugosa,* and discussing Coker's work Cleland says: "We have cristate plants which we assign to *C. cristata* and it seems advisable to apply a definite name to these more simple, non-cristate specimens, whose spores do not agree in size with *C. rugosa* of the English workers."

Coker's spore measurements for the *rugosa-Krombholzii* forms are 7-9.3 x 8-11μ, which is larger than in the South Australian form. But under the heading *cristata-cinerea* forms Coker gives spore measurements 5.5-8 x 6.7-10.5μ, so that it is not impossible to include *C. sub-rugosa* as a synonym of *C. cristata.*

Cooke records *Clavaria cinerea,* Victoria; *C. cristata,* Victoria, Queensland, Tasmania; *C. rugosa,* Queensland; *C. Krombholzii,* Victoria. Cotton and Wakefield regard *C. Krombholzii* as synonymous with *C. Kunzei* which they say has spores minutely apiculate, 3.5-4.5μ in diameter. Coker examined a plant identified as *C. Krombholzii* in Fries' collection. The spores are similar to those of *C. cristata.*

Group 7.

Clavaria Nymaniana P. Henn. Monsunia, 1, 1899, p. 9.

(Plate IV., Fig. 2.)

Plants branched irregularly or dichotomously, usually arising several together with the stems closely adpressed, but slender and distinct, up to 10cm. high, usually 5 cm. Branches closely adpressed one to another, axils rounded. Entire plant Slate Violet when fresh, fading to Wood Brown in age. Base of plant distinctly woolly and of the same colour as the plant.

Flesh rather brittle, concolorous with the surface when moist; if the plant is drying, white and cottony; becoming rather pliable towards the base, which is rather elastic and distinctly tough. (When the plant is deeply rooting or small this character is not so marked.) Taste and odour mild.

Spores not copious, white, with a bluish tinge in mass. Microscopically hyaline, smooth, sub-globose, 3-5.5μ with one guttule Habitat—on ground. Localities: Apollo Bay, Mount Evelyn.

C. amethystina Fr. ex Batt., as interpreted by Coker, shows certain similarities with this plant, viz., colour, tender and pellucid flesh and dichotomous branching. Coker's illustrations (pl. 24 and 25) suggest that his plant has the same habit as ours, but the

points in his description which do not agree are, (*a*) spores with one end pointed, (*b*) colour darker uppermost, tinted with buff at the base. In our plant the colour tends to persist at the base when it has faded from the upper parts, (*c*) base apparently smooth. In the Victorian plant the woolliness and toughness of the base is very marked.

Rea's description of *C. amethystina* gives the trunk as concolorous or whitish and the flesh tinged violet, becoming whitish, spores white, elliptical, obtuse at both ends 6-7 x 3-4μ. Cotton and Wakefield say that the smell is strong and the taste tallowy, stem scarcely distinct. Branching irregular, axils not flattened, branches often attenuated. Spores smooth, hyaline, globose, with a minute basal apiculus 5-7μ diameter, turning rapidly to yellowish on drying.

The spores of *C. amethystina* described above are much larger than in the Victorian plant, and in addition the colour and habit are not the same.

C. Nymaniana is closely related to the Victorian plant, and Henning's description fits the Victorian plant fairly well. The only difference lies in the fact that the stem of the true *C. Nymaniana* is smooth, but Henning also states that it is flexible. It has not been possible to obtain a type specimen of *C. Nymaniana,* but in view of the fact that its description agrees closely with that of our plant it is advisable to regard the two as belonging to the same species.

Group 8.

Clavaria subtilis: Fr. ex. Pers. Pers. Comm. T.4, fig. 2.

(Plate III., Fig. 2, Text Fig. 1*b*.)

Plants white, cream in age, slender, 2-4 cm. high growing separately or in tufts, usually with a distinct slender cylindrical stem equal to $\frac{1}{3}$ or $\frac{1}{2}$ the plant in height, from the top of which the few branches arise or branching at the base giving the appearance of two fascicled individuals: the branches are often bent so as to resemble prongs. Stem and branches smooth, glabrous, equal, axils patent. Tips often long, gently tapering to a blunt point. Flesh white, delicate, but rather tough. Internal structure of interwoven hyphae 4.5-8μ thick. Taste and odour none. Hymenium 30μ thick. Basidia with two or four sterigmata. Spores, white in mass, microscopically hyaline, smooth, oval, or rectangular-elliptical, with an oblique apiculus, once guttulate 3.5-4.3 x 2.2-3.6μ. Habitat—on damp soil in gullies, widespread in Victoria.

Coker describes *C. Kunzei* as a rough spored form, but he considers *C. subtilis* Fr. ex. Pers. to be a synonym. His illustration of *C. Kunzei* (pl. 29, Coker) suggests a different plant from the

one Bresadola gives, and also from the Victorian plants. But Coker has examined a plant labelled *C. subtilis* in the Bresadola Collection at the New York Botanical Garden, and says it is exactly like *C. Kunzei* in form and spores. Bresadola's description of *C. subtilis* is "Gracilis, sub-tenax, ramosa, ex albida pallide straminea, 3-4 cm. alta, basi subglabra. Trunco e ramis subaequalis vix 2 mm. crassis. Rami pauci dichotomi, subfastigati, apice attenuate, sporae ellipsoideae-ovoideae, basi distincte apiculatae, hyalinae, leves 3-5 x 2.5-4μ. Bas. clav. 25-30 x 5-8μ." Bresadola's illustration of the plant and its spores suggest that the plant he called *C. subtilis* is the same as our plant. The only difference lies in the fact that he shows spores with two guttules, while those of our plant have one.

Rea considers *C. subtilis* and *C. Kunzei* as separate species, but in neither case does he mention any spore markings. His description of *C. subtilis* fits our plant, except that the spores are larger in his form.

Coker's illustration of *C. Kunzei* suggests a different plant from the one under consideration, and the National Herbarium (Melbourne) specimen of *C. Kunzei* is quite different from it, as it shows an antlered type of branching and has rough spores, which do not resemble those of any plant of this group collected in Victoria.

It is therefore evident that the two plants *C. subtilis* and *C. Kunzei* are distinct species and may be identified briefly as follows:—*C. Kunzei* white, small, showing antlered type of branching, spores rough; *C. subtilis,* white, small, branches dichotomous, cylindrical, spores smooth.

Clavaria Kunzei Fr. Syst. Myc. 1, 474, 1821.

(Text Fig. 1*c*.)

Cooke (8) records this plant from Queensland and a specimen identified by him is in the National Herbarium, Melbourne. He describes it: "Rather fragile, white, very much branched from a thin base (2-6 cm. high), branches elongated, crowded, repeatedly furcate, fastigiate, even, equal, compressed at the axils. Spores sub-globose 9-12 x 8μ, hyaline. In Woods, Queensland."

There is no doubt that this specimen is correctly identified, as it fits Coker's description, but the spore measurements Cooke gives (sub-globose 9-12 x 8μ hyaline) are incorrect. The specimen has sub-globose, hyaline spores 2.5-3.5 x 3.5-4.5μ, which are very rough for their size. It is in a fragmentary condition and is brown in colour, but it shows the typical antlered branching and some scurfy-velvety areas, particularly at the top of the stem.

As the plant has not been collected in Victoria there has been no opportunity to make a description from a fresh specimen. Coker (7) gives an excellent description of the species.

CLAVARIA CINNAMOMEA n. sp.

(Plate III., Fig. 3.)

Plantae parvae gregariae vel solitariae, rarius simplices, saepius ramosae. Stirpes gracilis teres circa 1 *mm. lata, non radicans. Rami pauci dichotome summa ex stirpe nascentes. Ramis patentibus axiles partes inferiores ramarum saepe latae. Rami* 1-2.5 *mm. lati angustiores, teretes, latiores compressi, sulcus utrimque late apertus. Apices obtusi, raro acuti, in plantis juvenilibus obtuse dentate. Color stirpis "Mikado Brown" ad "Sayal Brown," rami superiores et apices "Cinnamon Buff" ad "Pinkish Buff." Sporae leves albae hyalinae gutta unica in distali spori extremo sita, ellipsoideae, extremo apiculo obliquo* 2.8-4.2 x 1.9-2.9μ *av.* 3.45 x 2.42μ. *Basidia quattior sterigmatis. Hab. ad terram in silvis. Loc. Cockatoo.*

Plants gregarious or solitary, small 1.5-4 cm. high, rarely simple, most often branched. Stem slender, cylindrical, about 1 mm. broad, occasionally slightly bent, not rooting. Branches few, arising dichotomously from the top of the stem. Branching open, axils and lower parts of the branches often flattened, branches 1-2.5 mm. broad, the narrower ones cylindrical and smooth, the broader ones often flattened, with a broad, open furrow on either side. Tips blunt, very occasionally pointed, in young plants bluntly toothed. Colour of stem Mikado Brown to Sayal Brown, of upper branches and tips Cinnamon Buff to Pinkish Buff. Spores smooth, white in mass, elliptical, microscopically hyaline, with one guttule situated in the distal end of the spore, with a prominent terminal apiculus 2.8-4.2 x 1.9-2.9μ, av. 3.45 x 2.42μ. Basidia with four sterigmata. Habitat: on ground in fern gullies. Locality: Cockatoo.

The plant is easily recognized in the field by its characteristic form which resembles that of *C. crocea*, and by its colour, which is always darker at the base. It is distinguished from *C. umbrinella* Sacc. by its smaller spores and rather fleshy texture. In addition the colour of *C. umbrinella* is uniform.

CLAVARIA UMBRINELLA Sacc. Syll. 6, 695, 1888.

Clavaria umbrina Berk. Outlines of Brit. Fung. Pl 18, Fig. 3-4, 1860.

Clavaria subumbrinella Imai. Trans. Sapporo Nat. Hist. Soc, xiii, Pt 4, p. 386, 1934.

(Fig *h.*)

Plants moderately small and simple, up to 5 cm. high, branching dichotomously three or four times from a slender stem which may be fused with others at ground level. The stem may be equal to as much as half or two-thirds the plant in height. Branches cylindrical, about 1.5 mm. diameter; axils rounded, not flattened. General trend of the branches upright. Tips relatively long, and tapering to a blunt point. Colour, Pinkish Buff to

Cinnamon Buff, but with slightly less pink than these shades. Base slightly tomentose, two-thirds of the plant upwards faintly white pruinose. Flesh whitish, firm, opaque, rather fibrous, smell and taste none. Spores, white in mass, microscopically hyaline, sub-globose, smooth, with a minute apiculus 2.2–3.2μ x 3.3-4.2μ. Habitat—on damp ground under scrub. Locality, Mt. Evelyn. Not previously recorded for Australia.

In general appearance the plant resembles *C. Bizzozeriana,* but may be distinguished by its colour and firm texture.

It is to be noted that in Rea's description of *C. umbrinella* the spores are slightly larger than in the Victorian plant, and also that the branches are distinct to the base. Our plant could be so described, or could be interpreted as a cluster of several plants fused at the base.

Imai (14) describes a species *C. subumbrinella* " solitaria, ter quaterve ramosa, umbrina (tawny olive) circa 5 cm. alta, ramis dichotomis, apicibus subacutis, stipite distincto, parte subterranea leniter albo-tomentosa, basidiis clavatis, sporis in cumulo albis crasso ellipsoideis, levibus circa 5 x 3. Hab. ad terram in silvis.

The fungus somewhat resembles *C. umbrinella* Sacc. and is distinguished by the slightly tomentose stipe and by the method of branching. *C. umbrinella* has no stipe and branches at the basal part of the plant ".

The only real points of difference between this species and *C. umbrinella* are, (*a*) the slight tomentosity of the base of the stem which is lacking in *C. umbrinella* (but the Victorian plant which fits the description of *C. umbrinella* shows this character), (*b*) the type of branching. The Victorian plants of *C. umbrinella* are all branched right to the base, but *C. Bizzozeriana,* which is obviously closely related, is found growing singly or fascicled in small groups of two or three, which could be regarded as one plant branching from the base (see plate). In this case there is no suggestion that the single plants and those growing in groups are of different species. Accordingly, as the descriptions of *C. umbrinella* and *C. subumbrinella* differ only in minor characters which are intermediate in the Victorian representative of the species, it is reasonable to regard them as synonymous.

CLAVARIA BIZZOZERIANA Sacc. Syll. 6, 693, 1888.

(Plate III., Text Fig. 1*j*.)

Clavaria tenuissima Sacc. Michelia 1, 436, 478 (not *C. tenuissima* Lev. Ann. Sci. Nat., 3rd ser., 5, 156, 1847).

Clavaria conchyliata Allen. Trans. Brit. Myc. Soc., 3, 92, 1908.

Plants branched, small and delicate 1-3.5 cm. high, solitary or a few together, growing on bare ground or amongst moss.

Stem slender, usually half the plant in height, often white pruinose below. Branching dichotomous and open, the branches cylindrical, comparatively long and slender and curved inwards slightly so that they resemble prongs. Axils rounded, not flattened, tips sub-acute, tapering gently to a blunt point. Young plants simple and club-like, about 1 cm. high and with a few small teeth at the apex. When young the entire plant is Slate Violet or Ramier Blue, in age the base becomes Avellaneous and the branches Greyish Lavender. Flesh solid, concolorous, fading with the surface, pliable, and except at the ultimate branches, which are very brittle and fragile, not snapping with a clean break when bent. Flesh of stem becoming fibrous in age. Spores smooth, hyaline, globose, 2.5-3.5μ diameter, minutely apiculate, white in mass, microscopically hyaline.

Our plants fit the description of *C. Bizzozeriana* as given by Cotton and Wakefield. But Coker considers *C. Bizzozeriana* a synonym of *C. pulchella* Boud. Boudier describes *C. pulchella* as having flattened branches and denticulate tips. The spores of his plant are 4–5μ long, oval. Also the stem and lower parts of the branches are white, only the upper parts of the plant being violet. Boudier's illustrations are reproduced in plate 3, fig. 4, and from these it can be seen that our plants do not resemble *C. pulchella* in form, having rounded branches, entire tips and globose spores, and an almost uniform violet colour. Coker has not seen *C. Bizzozeriana* in the living state but regards *C. exigua* Pk. as the same. The description he gives of *C. pulchella* (= *C. Bizzozeriana*) is adapted from Peck's account of *C. exigua*. From this description it may be seen that *C. exigua* and *C. pulchella* have a similar habit and colour distribution, and the spores are alike, so it is possible that they are synonymous. *C. Bizzozeriana* differs from them both in not having a white base, and in spore size. These differences are sufficient to justify keeping *C. Bizzozeriana* as a separate species.

In 1878 Saccardo first named the plant known as *C. Bizzozeriana*, *C. tenuissima*, but, as Leveille had, in 1847, already given another plant this name, Saccardo changed the name to *C. Bizzozeriana* in 1888. *C. conchyliata* Allen is regarded as synonymous with *C. Bizzozeriana* by Rea, and Cotton and Wakefield, and the descriptions agree well.

It is interesting to note that *C. arborescens* which Berkeley described from New Zealand (Hooker, Fl. N.Z., 11, p. 186, London, 1855) may be the same as *C. Bizzozeriana*.

The description is "sparsa, amethystina, gracilis, stipite tenui elongato, simplici, ramis furcatis fastigiatis, ultimis brevissimis, acutis". In the absence of details of spore characters it is impossible to be certain of the identity of the plant.

CLAVARIA CROCEA Fr. ex. Pers.

Pers. Comm. p. 57 (189), 1798.

(Plate IV., Fig. 3, Text Fig. 1*g*.)

Plants small, growing in groups, but not fascicled, 1–5 cm. high, branching from a slender stem, which is long or sometimes quite short, occasionally slightly tomentose, equal to about half the plant in height, in age a darker colour than the branches. Branches arising dichotomously from the top of the stem, three or four times furcate; axils rounded, often flattened, in which case the branches have an antlered appearance and show several broad, shallow longitudinal furrows. Branches often smooth and sub-cylindrical; tips blunt. Colour, Orange, Capucine Yellow, Orange Buff, the base of the plant darker than the tips. In age fading to Light Orange Yellow with somewhat yellower tips.

Flesh concolorous, soft and brittle, more flexible when old. Smell none, taste mild, occasionally bitter. Basidia with four sterigmata, spores distinctly rough, white in mass, microscopically hyaline, sub-globose once guttulate. In sheltered places, or among grass and moss in more open situations.

Cooke records this species for Victoria but gives an inaccurate spore measurement ("spores ellipsoid, 6–7 x 2–3μ"). Cleland has recognized it in South Australia and gives an illustration of typical plants, which are much smaller than the Victorian ones. Coker says *C. crocea* is one of the rarest Clavarias and is unsurpassed for delicacy and beauty. Although he says the plant has been collected only a few times since Persoon's day, it is not uncommon in Victoria and reaches a large size.

Cotton and Wakefield exclude *C. crocea* as being indeterminable The specimens on which Berkeley based the English record are at Kew but show no spores.

CLAVARIA PYXIDATA Fr. ex. Pers. var. *asperospora* n. var.

Pers. Comm. p. 47, (179), 1797.

Fr. Hym. Eur., 669, 1871.

(Plate IV., Figs. 1, 4, 5, Text Fig. 1*k*.)

Plants up to 10 cm. high, often extremely small, springing in clumps or singly from decaying wood. Main stem slender, sometimes somewhat pubescent, sometimes with brown hispid fibres at the base. "Stems round, often channelled, becoming thicker upwards dividing simultaneously like an umbel into several branches, which spread out rather strongly and then turn up again, primary branches expanding suddenly at their tips into little cups, from the margins of which spring the branchlets of

the third degree. These may again end in cups with similar branches which finally terminate in smaller cups with little teeth on the rims". (Coker, p. 94). Colour, Wood Brown to Avellaneous, base Cinnamon Brown. Flesh quite pliable and not at all brittle except at the tips, tough, especially at the base. Very peppery to the taste. Spores pure white in mass, definitely roughened, sub-globose 3.2–4 x 4–4.8μ. Basidia 4-spored, 3.5–4.6μ thick, inconspicuous, hymenium about 30μ thick with many projecting cystidia of two kinds, either fusiform, pointed, hyaline, and with scanty cell contents, or cylindrical with rounded tips, somewhat resembling the gloeocystidia of *Physalacria*. Hyphae just beneath the hymenium, fine, 3.5μ thick, varying to 11μ in the centre, clamp connections present. Always found growing on decaying wood (in Australia chiefly on Eucalypts, rarely on Acacias, etc.).

This species is very widely distributed in Victoria and in most temperate parts of the world. It is easily recognized in the field by the cup-shaped expansions at the ends of the branches, the brownish colour, and the peppery taste.

The form of *C. pyxidata* which occurs here shows certain differences from the type viz.: brown hispid fibres are often absent from the base, brownish colour even when young, and, chiefly, in having spores which are distinctly rough. The European and American plants are "rather light clear yellow" when fresh, have hispid fibres at the base and, in addition, smooth spores. Accordingly, although the two forms have exactly the same type of branching and both possess cystidia of two kinds, it was decided to describe the Australian plants as a new variety.

CLAVARIA PYXIDATA var. *asperospora* n. var.

Forma habitusque similis Clavariae pyxidatae *Fr. ex. Linn. Color "Wood Brown" ad "Avellaneous". Basis "Cinnamon Brown" pubescens saepe sine fibris hispidis, sporae hyalinae, subglobosae, perspicue asperae* 3.2–4 x 4–4.8μ. *Loc. Sherbrooke, Victoria.*

"Branching and habit like *C. pyxidata* Fr. ex. L. Colour Wood Brown to Avellaneous. Base Cinnamon Brown, pubescent, often without hispid fibres. Spores hyaline, sub-globose 3.2–4 x 4–4.8μ distinctly rough. Sherbrooke, Victoria".

I have examined plants from Victoria and Tasmania and find the characters mentioned constant. Cleland does not record the species for South Australia, Cooke records it for New South Wales and Victoria. Cotton and Wakefield do not recognize *C. pyxidata,* regarding it as possibly an abnormal form of *C. stricta*. It seems that they have not examined it in the fresh state, as it is one of the most easily recognized species. Its

peculiar type of branching is unmistakable; also its spores admit of no confusion with those of *C. stricta* as they are white and sub-globose; *C. stricta* has ochraceous, pip-shaped or elliptical spores 6–9 x 4–5μ.

Group 9.

Clavaria crispula Fr. Syst. Myc., 1, 470, 1832.

(Plate V., Fig. 2, Text Fig. 1*m*.)

Plants branched, up to 5 cm. high, growing in colonies among pure wood debris around or under trunks. Subiculum very extensive, white, ropy or effused, stems arising from this, about 2–3 mm. diameter, rather woolly at the base, and with several rhizomorphs attached. Stems branching a short distance above the base into two or three main branches, which divide irregularly or dichotomously once or twice to form a large number of fine ultimate branchlets, which are often less than 0.5 mm. broad, (usually 0.5–1 mm.). Branches rounded, rather flexuous, but generally tending in an upright direction. Tips subulate and divaricating.

Colour, creamy when fresh, Ochraceous when old, the tips usually lighter than the body of the plant; entire plant on drying Isabella Color. Flesh concolorous, creamy, not changing colour on bruising, soft and dry, not breaking when bent upon itself, pliable and resilient. On drying the branches become hair-like and very fragile.

Spores ochraceous, copious, slightly colored when examined microscopically, elliptical to pip-shaped, with an oblique terminal apiculus, 6–6.9 x 3.2–4.1μ distinctly roughened, almost spiny. Hymenium smooth, basidia with four sterigmata. Locality, Cockatoo. May. Not previously recorded for Victoria. Recorded by Cooke (8) for Western Australia.

The soft toughish texture of this plant distinguishes it from any other *Clavaria* occurring in Victoria. Rea (16) gives Massee's description of *C. crispula*. This fits our plant, except that the spores are said to be 5 x 3μ. These are slightly smaller than those of the Victorian plant, but Massee makes no reference to their roughness. Cooke also gives Massee's description. Coker (7) lists *C. crispula* as a doubtful synonym of *C. decurrens* Fr. ex. Pers., but comparing our plant with Coker's description of *C. decurrens* it is evident that they are not the same. The flesh of *C. decurrens* stains pink when bruised, the branches are angular and flattened, and the spores are smaller than in our form, which has rounded branches, the flesh not staining pink when bruised. Another point is that in our plant the hymenium is single. In *C. decurrens* it proliferates. The Victorian plant

is distinct from any other I have collected, and, as it fits the description of *C. crispula* as understood by Massee and Rea, I would prefer to regard it as distinct from *C. decurrens*, as described by Coker and to place it in the species *C. crispula.*

CLAVARIA GRACILIS Fr. ex. Pers. Comm. p. 50 (182) 1797.
(Plate V., Figs. 1 and 3. Text Fig. 1*l*.)

Clavaria alutacea Lasch. in Rabenhorst Klotzschii Herbarium Vivum, Mycologicum Cent. 16, No. 1519, 1851.

Clavaria fragrans E. & E., N. Am. Fungi, 2nd ser., No. 2033, 1888.

Clavaria fragrantissima Atk., Ann. Myc., 6, 57, 1908.

Clavaria flavuloides Burt., Ann. Mo. Bot. Gard., 9, 28, pl. 5, fig. 34, 1922.

Plants 3–9 cm. high, 1–6 cm. broad, gregarious, often crowded in extensive clumps, sometimes growing in rings. Plants slender and delicate, varying to large and rather firm, mycelium forming a distinct layer beneath the surface of the mass of pine needles, and binding the needles and other debris together. Trunks 3–7 mm. diameter, 1–3 cm. in length, arising directly from the mycelium, with a few large rhizomorphic strands attached; branching dichotomously six or seven times in an upright fashion, the ultimate branches ending in short, acute irregular processes which often divaricate. Branches usually flattened at the axils, which tend to be lunate in the lower parts of the plant, but somewhat compressed in the upper parts. Colour, body of the plant Warm Buff or Light Ochraceous Buff or paler; tips, Ochraceous Salmon or Whitish. Flesh paler than the surface, not changing colour when cut or bruised, soft and delicate, but not brittle. Odour distinct, faintly medicinal, disappears on drying, taste faint, but similar. Spores pale ochraceous, broadly elliptical with an obliquely terminal mucro, slightly rough, varying to almost smooth, 3.3–4.9 x 4.8–6.2μ. Basidia 4.5–6μ thick with four sterigmata, hymenium 40–50μ thick. Threads of flesh and subiculum between 3 and 9μ wide, showing clamp connections. Habitat, among fallen needles beneath *Pinus insignis*. Locality, Durdidwarrah, Brisbane Ranges. June. Not previously recorded for Victoria. Recorded by Cleland for South Australia. This plant is readily recognized in the field by its place of growth, slightly fragrant odour and by its colour.

Coker's illustrations and descriptions are in very close agreement with the plant as it occurs here. He states that Persoon's original description fits the American plants perfectly.

CLAVARIA STRICTA Fr. ex. Pers. Hym. Eur. 673.
(Plate V., Fig. 4. Text Fig. 1*n*.)

Lachnocladium Atkinsonii Bres. Journ. Myc. 8, 119, 1902.

Clavaria leucotephra B. & C. Grevillea 2. 7, 1873.

Clavaria condensata Fr. Epicr., p. 575, 1838. (Sense of Bresadola and Romell.)

Clavaria syringarum Pers. Myc. Europ. 1, 164, 1822.
Clavaria Kewensis Mass. Journ. Bot. (Britten's) 34, 153, 1896.
Lachnocladium odoratum Atk. Ann. Myc., 6, 58, 1908.
Clavaria Lorithamnus Berk. Aust. Fungi, No. 46, Journ. Linn. Soc. London, 1872.

Plants branched, up to 7 cm. high and 5 cm. broad, growing on decaying wood, or on soil with a large admixture of wood debris; stem arising from a more or less distinct hyphal layer and usually with several white rhizomorphic strands attached to it, slender, pubescent, dividing rather quickly and irregularly into many smaller branches which, after branching once more, divide to form the pointed apices. Axils very narrow, not flattened. Branches always very erect, top of the plant usually pointed. Colour of main part of the plant between Honey Yellow and Isabella colour, or Ochraceous Buff or Light Ochraceous Buff, tips creamy. Taste and smell like radish, and rather strong. Flesh soft and translucent but tending to be tough, when old very brittle and watery. On drying, the plant becomes hard and the surface appears woolly and the colour becomes uniformly Chamois or Honey colour. Spores ochraceous, 3.5–4.5 x 6.3–9μ, elliptic with a large obliquely terminal mucro, distinctly rough, almost tuberculate in some collections. Basidia with four sterigmata 7–9.2μ thick about 40μ long. Localities: Healesville and Bayendeen. Not previously recorded for Victoria. In the field this species is chiefly distinguished by its compact appearance, erect branches, and strong smell and taste of radish.

The plant which I am calling *C. stricta* shows certain points of difference from the true *C. stricta.* It has no sterile areas of different appearance from the rest of the plant, showing a roughish, plush-like surface under a lens. These are said to be quite extensive in *C. stricta* as it occurs in other countries. The spores in the Victorian specimens are much rougher and slightly smaller than for well authenticated specimens of *C. stricta.* Of *C. stricta* it is said that many spores show the contents collapsed away on one side, near the mucro, giving the appearance of a very long and abrupt mucro. I have not observed this.

Cooke recorded *C. stricta* for New South Wales and Queensland and his description fits our plant very well.

Clavaria lorithamnus Berk. is described as "pallid umber, branches straight, apices shortly bifid and rather acute, 4 cm. high, spores hyaline. On the ground, Victoria. This is said to have exactly the form of *C. stricta,* but to have no rhizomorphs at the base."

Some of the specimens of *C. stricta* which have been sent to me have been reported as growing on the ground, but further

enquiries revealed that they were attached to buried wood or to be growing in soil rich in decaying wood, and in some cases rhizomorphs were absent.

I have not been able to obtain a specimen of *C. lorithamnus*, but in view of the occurrence of *C. stricta* without rhizomorphic strands there is no doubt that *C. lorithamnus* is merely an abnormal form of it.

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Explanation of Plates.

All illustrations are natural size.

Plate I.

Fig. 1.—*Clavaria muscoides.* Simple plants.
Fig. 2.—*C. muscoides.* Large complex plant.
Fig. 3.—*C. cristata.* Small, sparingly branched, white form.
Fig. 4.—*C. cristata.* Incrassated *cinerea* form.
Fig. 5.—*C. cristata.* *Rugosa* form.

Plate II.

Fig. 1.—*Clavaria cristata.* Most of these plants show the wrinkling of the surface typical of the *cinerea* form, but there is also a tendency towards the production of cristate branches in the upper parts of the plants.

Plate III.

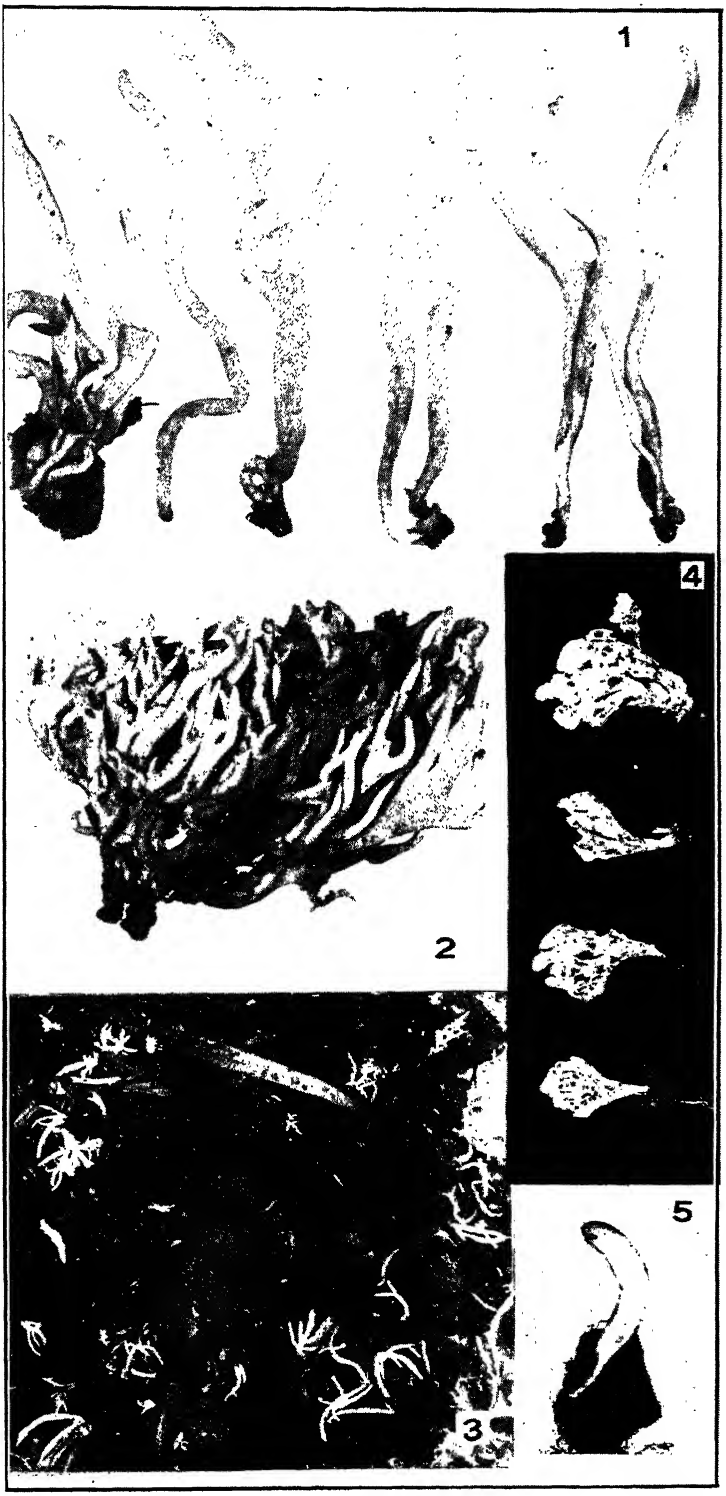
Fig. 1.—*Clavaria Bizzozeriana.* All types of plants between simple clubs and relatively large and complicated forms are shown. (The tips of some plants are shrunken through drying.)
Fig. 2.—*C. subtilis.*
Fig. 3.—*C. cinnamonea* (type).
Fig. 4.—Boudier's illustrations of *C. pulchella*, *iia* shows entire plant with white base, *iid* the denticulate tips and *iie* the elongated spores.

Plate IV.

Fig. 1.—*Clavaria pyxiduta* var. *asporosposa,* showing branches arising from cup-like expansions. Medium sized plants.
Fig. 2.—*C. Nymaniana.*
Fig. 3.—*C. crocea.*
Fig. 4.—Minute plants of *C. pyxidata.*
Fig. 5.—Large single plant of *C. pyxidata* var. *asherospora.* Notice that the branching is typical in the upper parts of the plant, but thickening of the branches at the base has obscured the cup-like expansions.

Plate V.

Fig. 1.—*Clavaria gracilis.* Two clumps composed of small plants.
Fig. 2.—*C. crispula.*
Fig. 3.—Large plant of *C. gracilis.*
Fig. 4.—*C. stricta.* Single plant, base missing.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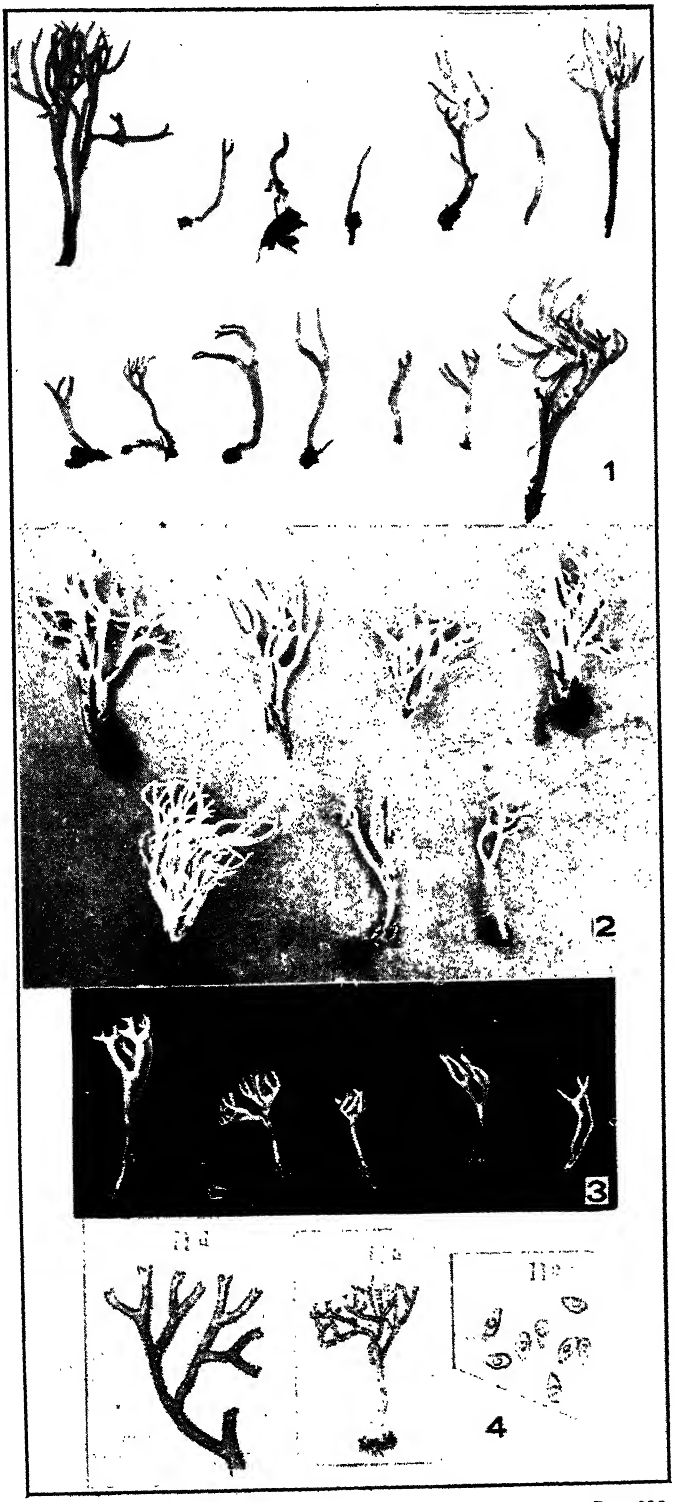
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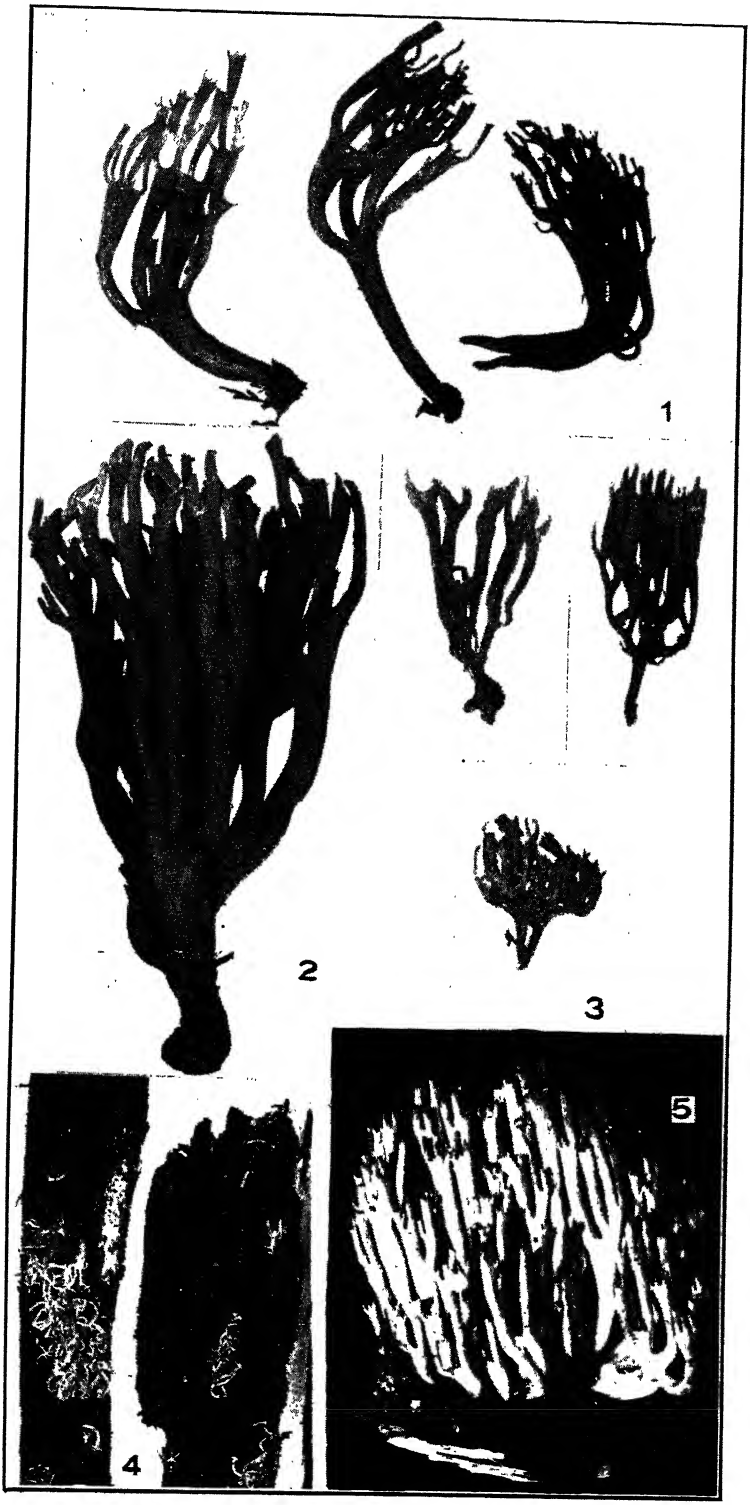
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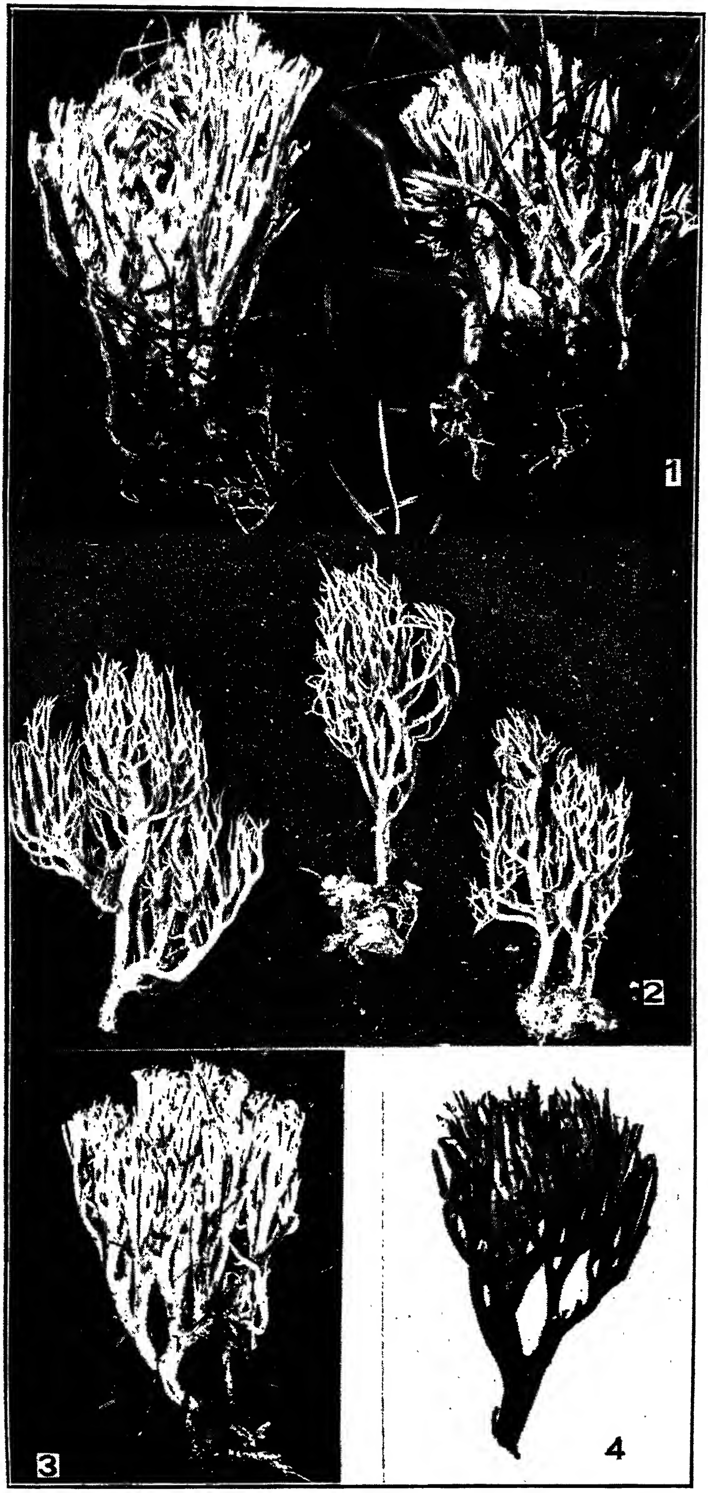
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[PROC. ROY. SOC. VICTORIA, 51 (N.S.), PT. I., 1938.]

ART. II.—*Granite and Granodiorite at Powelltown, Victoria, and their Relationships.*

By GEORGE BAKER, M.Sc., ALAN GORDON, B.Sc., and D. D. ROWE.

[Read 12th May, 1938; issued separately, 23rd January, 1939.]

Introduction.

The main purpose of this paper is to record the relationship between granodiorite and granite at Powelltown in the parish of Beenak, County of Evelyn, about 45 miles due east of Melbourne (fig. 1).

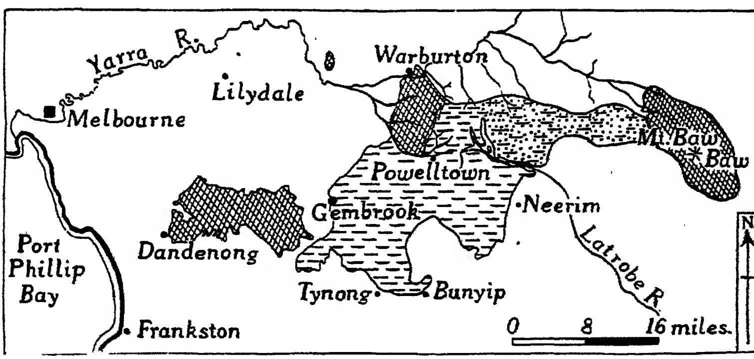

FIG. 1. Locality Map showing the Relationship of Outcrops of Granodiorite (cross hatching) to Granite (broken horizontal lines). Stippled area represents unclassified granite rocks.

The close proximity of granodiorite and granite in the Powelltown district was discovered by Mr. A. Gordon in 1936; field work which showed that the granite intruded the granodiorite was carried out by the authors in September, 1937, and the petrological relationships and the manuscript have been prepared by the senior author. The map accompanying the paper is based on contour plans prepared by the Forests Commission and by the Defence Department of Victoria.

Rock exposures in the Powelltown area are limited by conditions which have been very favorable for the accumulation of rock debris and soil. The examination of the granitic rocks was confined to a few road cuttings, a quarry, timber track clearings and one or two cleared hills on which soil erosion has occurred. Stream courses supply sparse geological exposures since sands, gravels and soils are deep, and plant growth very luxuriant, masking all critical geological boundaries. The information obtained from the area, however, is sufficient to indicate that of the two plutonic intrusions present, viz., granodiorite and granite, the granite is the younger.

The topography of the area is essentially a youthful one, characterized by fast flowing mountain torrents which drain into the mature valleys of the Latrobe River and the Little Yarra River. These are the two main streams in the area, the Latrobe flowing in an easterly direction, and the Little Yarra in a diametrically opposed direction. Whereas the tributary valleys of these two rivers are very youthful in aspect, with downward cutting far in excess of lateral widening, the mature valleys of the Latrobe and Little Yarra have built up flood plains nearly a quarter of a mile wide. The low divide which separates the Latrobe from the Little Yarra River in the eastern portion of the area, is locally known as The Bump; it is no more than 50 to 75 feet above the two rivers, and is barely a quarter of a mile wide. Minor streams in the area trend in two directions mutually at right angles, which suggests that two major systems of rectangular joints in the two intrusions are similar in strike and control the stream directions. The trend of the Little Yarra River has been mainly determined by the boundary between the granodiorite and the granite.

Nature and Distribution of the Rocks in the Area.

The rocks of the Powelltown District consist of granodiorite and granite with numerous xenoliths and three small areas of Silurian sediments. The granodiorite is a large stock occupying the north-western portion of an extensive area mapped as granitic rocks on the geological map of Victoria. The bulk of this mapped portion is a batholith of granite, extending from Powelltown in the north, to Gembrook in the south-west, Neerim in the south-east, and Tynong, Garfield, and Bunyip in the south as shown on fig. 1. The rock from Mt. Baw Baw has been described and mapped as granodiorite (2), but its extent and relationship to the granite have not been indicated.

Altered Sediments.

The small isolated areas of sediments are probably Silurian because rocks of this age occur a mile or so west of Three Bridges and outcrop as normal mudstones from here to Yarra

junction. The main localities are (i) the head of Blackwood Gully, north of Reid's timber mill site, (ii) on the north side of the road south-east of Mt. Myrtalia, (iii) on the timber track between Powelltown and Gilderoy, and (iv) near the junction of Black Sands Creek and the Little Yarra River, about half a mile beyond the western limits of the map.

In addition to these occurrences, occasional residual boulders and pebbles occur on Big Bertha firebreak, in Seeley's Creek and just north of Lloyd's timber mill site. The outcrops in the north-central portion of the area are probably either roof pendants in the granite or rafts of included sediments; they occur some 80 yards or so from the boundary between the granite and granodiorite, and therefore do not form a continuous sheet separating the two intrusions. The outcrop between Powelltown and Gilderoy is a small remnant surrounded by hillwash. Near the junction of Black Sands Creek and the Little Yarra River, the Silurian cannot be observed in contact with the granodiorite because of soil and vegetation.

The Silurian rocks consist of hornfels, quartzite and slightly metamorphosed sandstones which occur on the surface as fragments, no definite bedding being visible. The width of the metamorphic aureole is indeterminate; it could not have been very great, since narrow remnants in the granite near the granodiorite boundary consist of slightly altered sediments as well as metamorphosed types.

Granodiorite.

The granodiorite occurs in the north-western part of the area; it is continuous from Powelltown to Warburton in a northerly direction, and the area of the outcrop is about 45 square miles. The rock is fine-grained, and as at Warburton, contains occasional quartz nodules (4, p. 174).

The best exposures occur in cuttings along the Black Sands Creek road, and in the northern part of the area where recent road construction has exposed fresh rock. Reasonably fresh outcrops occur near the granite boundary half a mile or so north of Reid's, along the timber track clearings.

Granite.

The granite covers a larger area than the granodiorite, occupying the southern, eastern and north-eastern portions of the area. Beyond the area, the geological map of Victoria shows it to be continuous with the granite at Gembrook. It has a porphyritic character and is much coarser-grained and lighter in colour than the granodiorite.

A road cutting between Powelltown and Nayook West has exposed fresh granite near Old 13 timber mill site, and a large face has been exposed in a ballast quarry at The Bump, near

Nayook West. At this quarry, portions of the granite have undergone pneumatolytic alteration, and portions have been altered to a clayey mass consisting of halloysite, a mineral of the kaolin group, which also occurs as veins following the joint planes in the granite.

XENOLITHS.

Xenoliths are more common in the granodiorite than in the granite, and never exceed 12 inches across, being often as small as half an inch in diameter. They are usually fine-grained, but may occasionally be porphyritic. Some contain numerous biotite clots, and some show well marked schistose structures, especially those contained in the granodiorite in the western portions of the area. Schistose examples are infrequent in the granite.

Both melanocratic and leucocratic types are represented; by granitisation, the melanocratic examples become lighter in colour, and with mechanical disintegration, become strewn about in the host rocks, their presence being detected by indistinct spots or by clots of ferromagnesian minerals in the plutonic rocks. The leucocratic xenoliths comprise rare examples of quartzite which sometimes exhibit junctions with altered argillaceous types.

In rare examples, stringing out and partial granitisation of some of the xenolithic material has resulted in the production of imperfect schlieren-like structures in the granite, but such have not been observed in the granodiorite. Occasional pools of granitic material have been introduced into some of the inclusions, and in others, the dark coloured ferromagnesian minerals are more concentrated at junctions with the host rock.

The xenoliths invariably possess rounded outlines, produced by magmatic corrosion or by the breaking off of curved portions due to expansion on immersion in the hot magma. Contacts with the host rocks are often embayed, and at times the margins of the xenoliths are pronouncedly inshot with granitic material.

DYKES AND VEINS.

Veins and occasional vughs of pegmatitic quartz and felspar with tourmaline and bladed biotite, cut the granodiorite near the boundary with the granite along Seeley's Creek, on Big Bertha firebreak and north of Reid's. Partially kaolinised pegmatite also cuts the granite in the quarry at Nayook West.

Fragments of fine-grained aplite are common on the surface throughout the area, and in a few examples veins of aplite 1 inch wide and dykes up to 5 feet in width, cut through granodiorite and granite, but no examples could be traced laterally for more than a distance of 20 feet.

Quartz veins cut through Silurian quartzite north of Reid's where there is also a two inch vein of granite cutting the granodiorite. In this vein of granite, biotite is not as abundant as in the more normal portions of the main mass of the granite, and its contact with the granodiorite is relatively sharp.

Relationship of Granodiorite and Granite.

Although contacts between the granodiorite and granite at Powelltown are masked by rock debris and dense vegetation, several factors exist which indicate the relationship of the two intrusions. As far as their age is concerned, all that can be adduced from this area is that they are post-Silurian and pre-Recent. Evidence from other parts of Victoria indicates that the granodiorites and granites are generally Upper Devonian or early Carboniferous, and by analogy the Powelltown occurrences are considered to be of similar age.

Observations which serve to indicate that the granite is younger than the granodiorite are as follows:—

(i) In the hills south and east of the junction with the granodiorite, the granite is usually porphyritic, with the groundmass medium, even-grained, but in parts along the line of contact, it is not so noticeably porphyritic and is rather finer-grained, suggesting that the granite was chilled against already solidified granodiorite.

(ii) Xenoliths of sedimentary origin are numerous in the granodiorite right up to the granite contact, but in the nearby granite only one xenolith of sedimentary parentage has been observed, although sedimentary xenoliths are abundant in the granite further away from the contact. It is assumed from this that the granodiorite intruded the Silurian first, obtaining numerous xenoliths from stoped off blocks of sediment; the granite followed at a later date, and transected both the Silurian and the granodiorite, obtaining more xenoliths from the Silurian rocks than from fragments already contained in those portions of the granodiorite which became engulfed in the granite.

(iii) Near the contact on Big Bertha and north of Reid's, the granite contains included blocks of granodiorite with sedimentary xenoliths in them.

(iv) The abundance of aplite, quartz and pegmatite veins and dykes in the granodiorite near its contact with the granite, especially on hill slopes near Seeley's Creek and north of Reid's, is suggestive that the granite is the younger of the two intrusions.

(v) Near the contact north of Reid's, a vein of granite 2 inches wide cuts through a large boulder of granodiorite.

There are no metamorphic changes visible along the line of contact, but microscopic investigations show that samples of granodiorite from near the contact possess more abundant quartz, occasional pools of which are in optical continuity; orthoclase crystals are larger and more numerous; occasional micrographic intergrowths occur, and the lime felspars frequently show sericitisation. These factors indicate slight thermal metamorphism of the granodiorite, with the introduction of small amounts of granitic constituents.

Petrology.

ALTERED SEDIMENTS.

The less altered Silurian rocks consist of fine-grained micaceous sandstones in which quartz grains are set in a ferruginous or argillaceous cement containing muscovite, rounded zircon, biotite, iron ores and rare tourmaline. In examples from north of Reid's, quartz is set in an aggregate of sericite fibres and chlorite.

The quartzites are fine-grained rocks which have developed from the recrystallization of relatively pure sandstones; any impurities present have been metamorphosed to form rutile, biotite, muscovite, apatite, zoisite and iron ores in small amounts, or have remained as unaltered, rounded grains of zircon. Some of the original sediments from which the quartzites developed were not quite as pure as others, since they possess greater quantities of muscovite; pneumatolytic tourmaline has been introduced into some of the quartzites. One variety of the quartzites was apparently developed from the alteration of a calcareous sandstone for it contains abundant grains of diopside interstitial to the quartz grains. The texture of this diopside quartzite is granoblastic, sphene occurs in subordinate amount, and the only other minerals present are rounded zircon and occasional ilmenite.

In some types of hornfels, the laminations present are suggestive of preserved bedding planes, but the majority are dense and even-grained. Spotted hornfels from the firebreak on Big Bertha is composed of cordierite, biotite, muscovite, some quartz, rounded zircons and iron ores, and the spotted appearance is due to the cordierite which is often crowded with numerous small plates of biotite. Cordierite-biotite hornfels from near the junction of Black Sands Creek and the Little Yarra River, is comparable with types described from the Bulla contact zone (7),

containing cordierite, biotite, iron ores, rounded zircons, apatite, muscovite and tourmaline. Quartz-biotite-cordierite hornfels from the right bank of Seeley's Creek, but not in situ, is coarser-grained than the cordierite-biotite hornfels and has a more vitreous lustre; some of the cordierite crystals in it have been corroded by the quartz.

In all these metamorphosed sediments, even when they occur as xenoliths, the original rounded detrital grains of zircon persist unchanged by metamorphism.

THE GRANODIORITE.

The granodiorite is a fine and even-grained rock composed of quartz, orthoclase which is sometimes microperthitic and poikilitic, oligoclase-andesine, abundant biotite with numerous inclusions and pleochroic haloes, chlorite with sphene and ilmenite along the cleavage planes, apatite and zircon, and occasional small veins of tourmaline which sometimes replace biotite. Symplektitic intergrowths occasionally develop at orthoclase-plagioclase contacts. Portions of the granodiorite near the granite boundary show slight changes due to metamorphism. The introduction of numerous small patches of quartz has developed a sieve structure in the biotite in parts of the rock.

Micrometric analyses of the granodiorite at Powelltown and Warburton (4, p. 173) show the main minerals to be present in the following proportions:—

TABLE 1.

—	I.	II.
Quartz	31·2	28·1
Orthoclase	16·3	12·4
Plagioclase	31·6	34·5
Biotite	18·6	24·0
Accessories	2·3	1·0

I.—Granodiorite, Powelltown.
II.—Granodiorite, Warburton.

The Powelltown analysis, representing the southern, and the Warburton analysis representing the northern portion of the intrusion are closely similar. Table 1 shows that quartz, orthoclase and accessory minerals are slightly greater, whilst plagioclase and biotite are smaller in amount at Powelltown. This is perhaps due to the proximity of granite and the assimilation of sedimentary material at Powelltown, whilst at Warburton, the granodiorite has no known neighbouring intrusion of granite from which additional quartz and orthoclase could have been introduced, and has assimilated dacite as well as sediments.

The following table (Table 2) indicates that the heavy mineral assemblage and index number of the granodiorites at the widely separated localities of Powelltown (I.) and Warburton (II.) are again similar:—

TABLE 2.

—	I.	II.
Apatite (colourless)	C	C
„ with pleochroic cores	V	..
„ (corroded)	V	..
Biotite	A	A
Chlorite	o	A
Garnet	V	V
Hornblende	..	r
Hypersthene	..	o
Ilmenite	V	o
Pyrite	o	r
Sphene	V	..
Tourmaline	V	..
Zircon (colourless)	o	o
„ (pale yellow)	V	V
„ (inclusions in)	o	r
„ (zoned)	V	V
„ (corroded)	V	V
„ (water clear)	V	V
„ ("torpedo")	V	V
„ (pyramidal)	V	V
Zoisite	V	o
Specific Gravity	2·72	2·72
Index Number	16·9	19·9

A = very abundant; C = common; o = occasional; r = rare; V = very rare.

At Powelltown, the tourmaline has been introduced from the later granite intrusion, whilst the hornblende at Warburton has been produced from the assimilation of dacite, and the hypersthene is probably a residual product of the dacite. The higher index number in the Warburton area is attributed to the presence of slightly more chlorite, biotite and ilmenite, generated from the breaking down of the hypersthene in dacite xenoliths.

THE GRANITE.

The granite is a light coloured, medium-grained to porphyritic potash granite containing orthoclase, quartz, acid oligoclase, biotite, secondary muscovite and accessory minerals. Orthoclase is often microperthitic; biotite does not contain nearly as many inclusions and haloes as do crystals of biotite in the granodiorite, and it sometimes shows dactylitic intergrowth with quartz. Chloritisation of the biotite is not uncommon, and the chlorite contains epidote as well as the other by-products of the alteration, sphene and ilmenite. Symplektitic pustules occur at some of the orthoclase-plagioclase contacts, and such intergrowths are more common in the granite than in the granodiorite of this area.

Veins of orthoclase which are interstitial between quartz crystals, show that the crystallization of the orthoclase overlapped that of the quartz; a similar occurrence in the granodiorite

suggests that this late-crystallization orthoclase may have been derived from partial soaking in of granite magma near the end stages of solidification. In some instances, quartz has embayed biotite plates, and in the bays, numerous small apatite and occasional zircon crystals included in the quartz, were formerly inclusions in the biotite. Occasional clusters of biotite plates associated with numerous apatite crystals are remnants of xenolithic strew, whilst poikilitic quartz and orthoclase also indicate digestion of xenolithic material.

In the quarry at Nayook West, portions of the granite have suffered pneumatolysis with the introduction of pyrrhotite, tourmaline and fluorite. This part of the granite is much poorer in biotite than the granite exposed elsewhere in the area, and contains microcline microperthite which is the last mineral to crystallize from the granite intrusion, since it often poikilitically encloses crystals of quartz, and also occurs in some of the veins cutting the granite.

The micrometric analysis in Table 3 is representative of the granite in the Powelltown district, being obtained from thin sections of samples from six localities; that of the You Yangs (1, p. 128) is added for comparison:—

TABLE 3.

—	I.	II.
Quartz	32·0	28·7
Orthoclase	34·7	34·8
Plagioclase	25·6	25·5
Biotite	5·7	8·8
Accessories	2·0	2·2

I.—Granite, Powelltown.
II.—Granite, You Yangs.

Although the mineral percentages are very similar for the two examples, variations occur in that the You Yangs granite is a soda-rich type and contains minerals like microcline, orthite and hornblende not recorded from the more normal portions of the potash granite from Powelltown. The amounts of orthoclase, plagioclase and accessory minerals in each type, however, are remarkably similar.

Table 4 illustrates the variation in the heavy minerals of the granite, sampled portions treated for heavy mineral analysis being obtained from Nayook West, Gembrook, Bunyip, Powelltown, Mount Beenak, Garfield and Tynong. Separation into light and heavy fractions was effected in bromoform of specific gravity 2.88. The index number is lowest for pneumatolysed portions from the quarry at Nayook West, and highest at Mount Beenak where slightly more biotite has been produced from rather

greater assimilation of xenoliths. The average index number for the three Powelltown localities (i.e., Powelltown, Nayook West and Mount Beenak) is 4.4 and the average specific gravity is 2.64, these figures being comparable with those obtained from the granite outcropping at Gembrook and Bunyip.

The heavy mineral indices and assemblages obtained from localities outside the Powelltown area are added for comparison, and it is seen that at Garfield and Tynong the granite has higher index numbers because local assimilation of included rock fragments has been greater, and basic clots and schlieren are more abundant. The variation in the index numbers is due to the generation of varying amounts of the ferromagnesian minerals consequent upon xenolithic digestion, but the primary accessory minerals, like zircon and apatite, remain fairly constant in amount and character throughout this granite massif.

TABLE 4.

	I.	II.	III.	IV.	V.	VI.	VII.
Index Number	1·8	4·7	4·8	4·8	6·5	10·1	10·3
Specific Gravity ..	2·61	2·63	2·64	2·64	2·66	2·68	2·64
Actinolite	..	..	..	..	V	..	..
Apatite (colourless) ..	o	C	o	C	o	C	C
" with pleochroic cores	..	..	V	V	V	..	r
Biotite	C	A	a	A	A	A	A
Chlorite	a	C	C	o	o	o	o
Epidote	..	V	..	V	..	V	..
Fluorite	V	..	..	V	..	..	V
Garnet	..	V	..	V	V	..	V
Hornblende	..	V	a	..	..	a	C
Ilmenite	o	r	r	C	C	o	V
Orthite	..	..	..	..	..	..	V
Pyrite	a	V	..	V	V	..	o
Rutile	..	..	..	..	..	V	..
Sphene	o	r	o	..	..	o	o
Topaz	..	V	..	..	..	V	V
Tourmaline	V	V	r	V	..	..	..
White Mica	r	V	V	V	V	V	V
Zircon (colourless) ..	o	C	o	o	C	C	C
" (pale yellow) ..	V	r	..	o	r	V	V
" (inclusions in) ..	o	o	C	o	o	a	a
" (zoned)	r	r	o	V	r	o	o
" (corroded) ..	V	V	..	V	V	r	..
" (water clear) ..	V	V	V	V	V	V	V
" (parallel growths)	..	..	..	..	V	V	..
" (acicular) ..	V	V	..	V	V	V	V
" (asymmetrical) ..	..	V	V	V	V	V	V
Zoisite	..	V	..	..	..	V	..

A = very abundant; a = abundant; C = common; o = occasional; r = rare; V = very rare.

I.—Nayook West.
II.—Gembrook.
III.—Bunyip.
IV.—Powelltown.
V.—Mt. Beenak.
VI.—Garfield.
VII.—Tynong.

XENOLITHS.

The xenoliths in the granodiorite are all sedimentary xenoliths, and present various stages in the contact metamorphism of the Silurian rocks. In schistose and foliated examples, the banding

arises from the parallelism of alternating laminae of biotite and quartz; this may be due to the original heterogeneity in the sediment as suggested for banded hornfelses (8, p. 64), or to stretching and flow banding resultant upon the movement of the hot plastic xenolith in the magma.

Microscopical examination shows that the xenoliths in the granodiorite may be either siliceous, aluminous, or characterized by actinolite, by biotite and plagioclase, or by biotite and orthoclase.

The siliceous xenoliths consist essentially of granular quartz and diopside; grains of sphene are common, actinolite surrounds some of the diopside crystals and may indicate the initial conversion of pyroxene to amphibole, a reaction produced during the cooling of the rock, and representing re-adjustment to conditions of lower temperature (8, p. 35); apatite, rutile, muscovite, rounded zircons, pyrite, pyrrhotite, orthoclase and plagioclase also occur. The rocks in this group represent schistose diopside quartzites which have been subjected to more severe metamorphism than they experienced as contact rocks, so that coarser-grained textures and alignment of the constituents have been produced.

The aluminous xenoliths are schistose and foliated inclusions with variable amounts of spinel, corundum and sillimanite. They represent an early stage in the alteration of aluminous sediments. The spinel occurs in clusters and strings of idioblastic crystals (5, p. 38) similar to those occurring in silica-poor hornfelses (8, p. 44); it is the deep green pleonaste variety, and its presence marks the rock as one deficient in silica. Although free quartz is present in the same rock section as spinel and corundum, these two minerals are never in direct contact with the quartz, some of which has been introduced from the granodiorite magma. This occurrence of spinel and quartz together in xenoliths, indicates a lack of equilibrium and a limited condition of diffusion which is rapidly passed when mechanical disintegration of the xenoliths begins (3. p. 366), and with increased granitisation of these xenoliths, spinel and corundum are eventually changed to felspar. Read suggests that spinel-corundum xenoliths belong to the silica-poor members of the argillaceous-calcareous hornfelses, and that the surplus alumina of the sediments gave rise to the production of spinel (6, p. 449). Spinel-corundum xenoliths in the Powelltown district are considered to have arisen in like manner, being of sedimentary origin.

The corundum occurs as irregular crystals both patchy blue to colourless and deep blue (sapphire) in colour. It has been produced in the absence of free quartz from rocks relatively rich in sericite, and frequently occurs as idioblasts embedded in a granular matrix of orthoclase. The corundum has been

partially altered to a micaceous product containing irregular relics of the fresh mineral as also observed elsewhere (6, p. 447), and both the corundum and the spinel occur as armoured relics, the protective barriers around them being biotite, muscovite, sillimanite and orthoclase.

Iron ores, limonite, rounded zircons, rare oligoclase, zoisite and sphene are also present in the aluminous xenoliths. Orthoclase is poikilitic in examples which have been subjected to more advanced grades of metamorphism, and it includes abundant apatite rods. In some examples, pneumatolytic tourmaline and pyrite, and rare crystals of zircon have been introduced from the granodiorite.

The xenoliths characterized by the presence of actinolite consist of plagioclase, actinolite containing rare residual grains of augite, biotite, abundant apatite, lobate growths of quartz in optical continuity, ilmenite, rounded zircons, rare rutile and zoisite. They were formed from sediments containing small amounts of lime originally.

The biotite-rich xenoliths consist of two types, one in which plagioclase felspar is dominant, and another with orthoclase as the dominant felspar; in each of these types, quartz and biotite are about equally developed. They were produced from sediments which initially contained equivalent amounts of silica and alumina, but varying amounts of potash. The biotite-rich plagioclase xenoliths form the most abundant inclusions in the granodiorite; they are dark and fine-grained, having biotite arranged in decussate structures. The granodiorite adjacent to these xenoliths contains xenocrysts of rounded zircon and rutile, whilst orthoclase and plagioclase are often poikilitic and the plagioclase crystals are sometimes zoned with remnants of xenolithic material. Some of the biotite in the granodiorite close to the xenoliths, and much of it in the xenoliths, is sieved by quartz, and occasional ocellar structures have been formed where the biotite was forced aside by growing crystals of quartz.

The biotite-rich orthoclase xenoliths were originally sediments poor in chlorite, but they apparently possessed abundant sericitic material; with advancing metamorphism, muscovite and subsequently orthoclase were produced from the sericite.

Xenoliths in the granite at Powelltown are of sedimentary and igneous origin. Amongst the sedimentary xenoliths, only two types have been recognized, the biotite-rich plagioclase xenoliths and the biotite-rich orthoclase varieties which are like those in the granodiorite except that most of them are more granitised. The xenoliths of igneous origin in the granite are reconstituted granodiorite; they contain large zircons with well-defined crystal faces and the grain size varies from fine to medium. Large plates of biotite contain haloes and inclusions as numerous as those

in the main mass of the granodiorite, and they have a definitely igneous aspect in contrast to biotite crystals developed from the alteration of the sedimentary rocks, where they always occur as small laths, often in decussate arrangements, or as elongated shreds.

Summary and Conclusions.

Two plutonic intrusions invaded Silurian sediments in the Powelltown district, one of them being granodiorite intruded as a stock, and the other a granite of batholithic nature. The limited field evidence indicates that the granite is the younger of these two intrusions.

Accidental xenoliths from both of these igneous masses have been grouped according to the main variations in composition as reflected by the mineralogical associations. Different textures have been produced in the xenoliths corresponding to the different degrees of thermal metamorphism to which they have been subjected. The fact that xenoliths in the granite are more granitised and drawn out into schlieren than corresponding types in the granodiorite, which often still retain traces of sedimentary structures, lends support to the conclusion that the granite is the younger of the two intrusions.

There has been no sedimentation or igneous activity between the late Devonian or early Carboniferous intrusive period and the deposition of Recent hillwash and alluvium. Agents of erosion must have been actively at work throughout this time to have removed practically all of the Silurian cover and expose and dissect the underlying granitic rocks.

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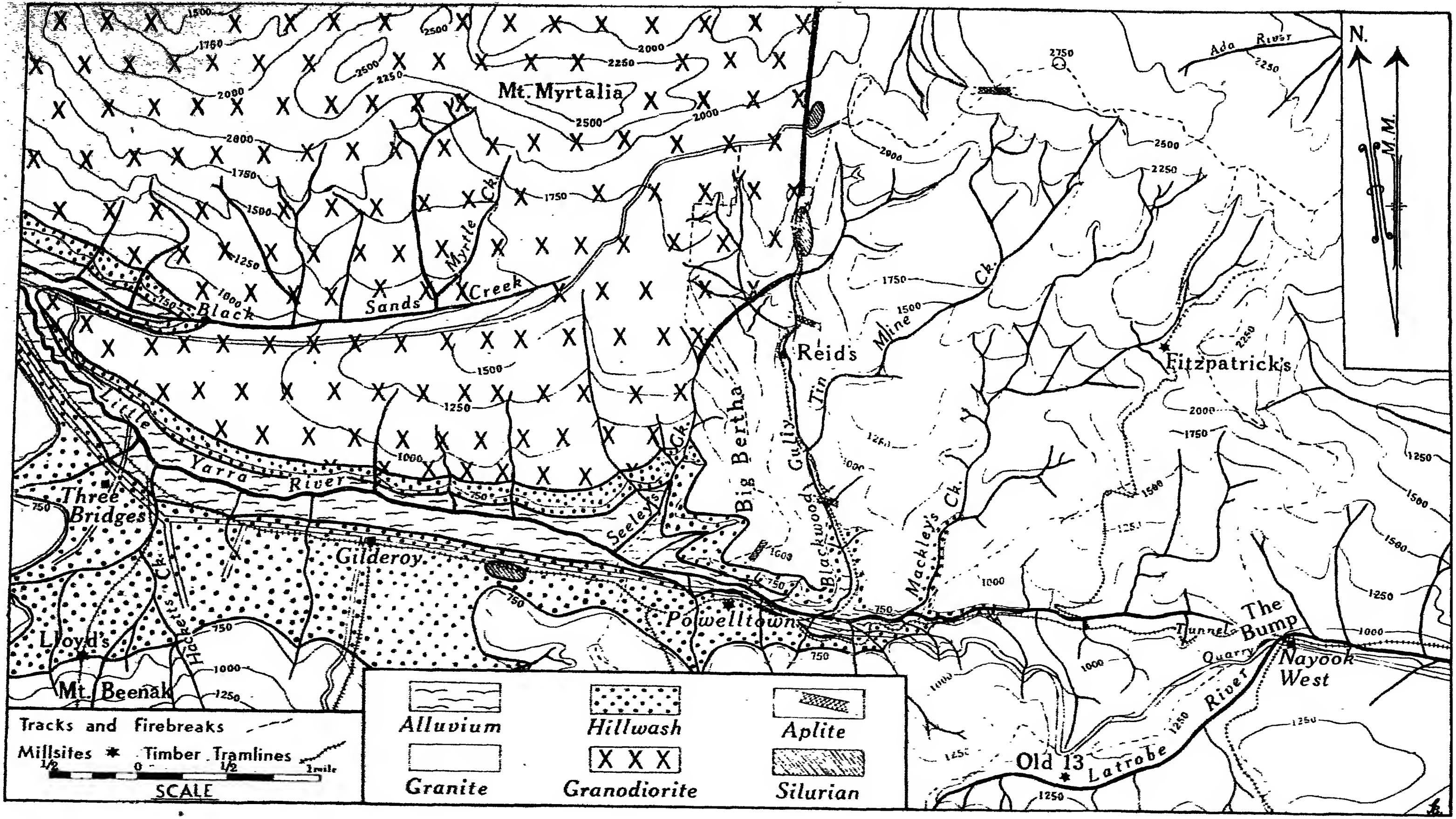
N.
M.M.
Mt. Myrtalia
Ada River
Fitzpatrick's
Reid's
Tin Mine Ck.
Big Bertha
Gully
Blackwood
Mackley's Ck.
Myrtle Ck.
Sands Creek
Black
Little Yarra River
Seeley's Ck.
Three Bridges
Gilderoy
Powelltown
Hacketts Ck.
Lloyd's
Mt. Beenak
Tunnel
The Bump
Quarry
Nayook West
Latrobe River
Old 13
Tracks and Firebreaks
Millsites
Timber Tramlines
SCALE
1 mile
Alluvium
Hillwash
Aplite
Granite
Granodiorite
Silurian

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Art III.—*The Physiography of the Echuca District.*

BY WM. J. HARRIS, B.A., D.Sc.

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Contents.

I. Introduction.

At first sight the wide-spread plains of northern Victoria and southern Riverina do not suggest physiographic problems, but closer examination shows several interesting features in the area of which the town of Echuca is the centre. The most evident of these features is the great bend the Murray River makes to the south when about 30 miles north-east of Echuca, but this is only one of many associated features which give a physiographic unity to the district.

The area treated in this payer is a strip about 70 miles long, extending from south-east of Rochester (Victoria) to Deniliquin (N.S.W.). The width of the more important part of the strip is only a few miles, though for its study a greater area has to be included in the northern part so that the general map has something of the shape of a tau cross.

II. Previous Workers.

As far as the writer is aware no general account of the area has been published. Gregory (1) in his Geography of Victoria mentions the bend of the Murray to the south and explains it by saying that the river has here cut through the raised flood plain which borders it further east. The problem is more complex than this explanation would lead one to infer.

The New South Wales Lands Department has published a plan of part of Riverina District, extending from Wagga to Balranald, on a scale of 4 miles to the inch. Generalized contours are shown at vertical intervals of 5 feet and provide a key to

the understanding of the area. On the Victorian side the State Rivers and Water Supply Department has prepared parish plans of irrigable districts with 1-ft. contours and with spot heights shown to 1/100 ft. at intervals of 5 chains or closer if necessary. These plans, on the scale of 20 chains to the inch, are as accurate as could possibly be desired for the study of drainage problems since they have been prepared for that special purpose. From their vertical scale the plans necessarily cannot represent higher areas but in such areas detailed levels are not required for our present purpose. The fact that plans can be prepared on such a scale gives a good idea of the general flatness of most of the area. In one part—north of Corop and north-west of Lake Cooper—no detailed survey was made as this part of the district was unsuitable for irrigation, the northern portion especially being low-lying and swampy.

It is possible that among the professional papers of the Victorian Water Supply Commission there may be reports which contain information or theories regarding the area but I have seen none.

Many of the physiographic features of the Victorian portion of the area, such as the condition of Lake Cooper when settlement first reached the district, the low banks of the Murray at Barmah, and the course of streams across the line of the Bama sand-hill are mentioned in an account of early settlement written by E. M. Curr (2) who made several journeys from Colbinabbin to the Murray River nearly a century ago and who was the first settler on the lower Goulburn.

III. Acknowledgments.

I wish to acknowledge my debt to the N.S.W. Irrigation Commission (Sydney) for the map of Riverina already mentioned, and to the engineers in charge of the Victorian Water Supply Districts of Rochester (Mr. H. E. Harding) and Tongala (Mr. C. Gallop) for assistance with plans and for giving me the benefit of their thorough—and probably unique—knowledge of the drainage of those districts. My attention was directed to the study of the subject by a conversation some years ago with Mr. A. S. Kenyon.

As on every other occasion when I have needed assistance, Mr. W. Baragwanath, Director of the Geological Survey of Victoria, and his officers have done all in their power to help me. This help has been particularly valuable in the preparation of the plans, etc., which accompany this paper.

IV. General Physiography.

A glance at a map of south-eastern Australia shows that the Murray River marks a very definite drainage line. Its southern tributaries flow into it more or less at right angles, though usually directed downstream (particularly in the case of the Goulburn)

GENERAL MAP OF ECHUCA AREA

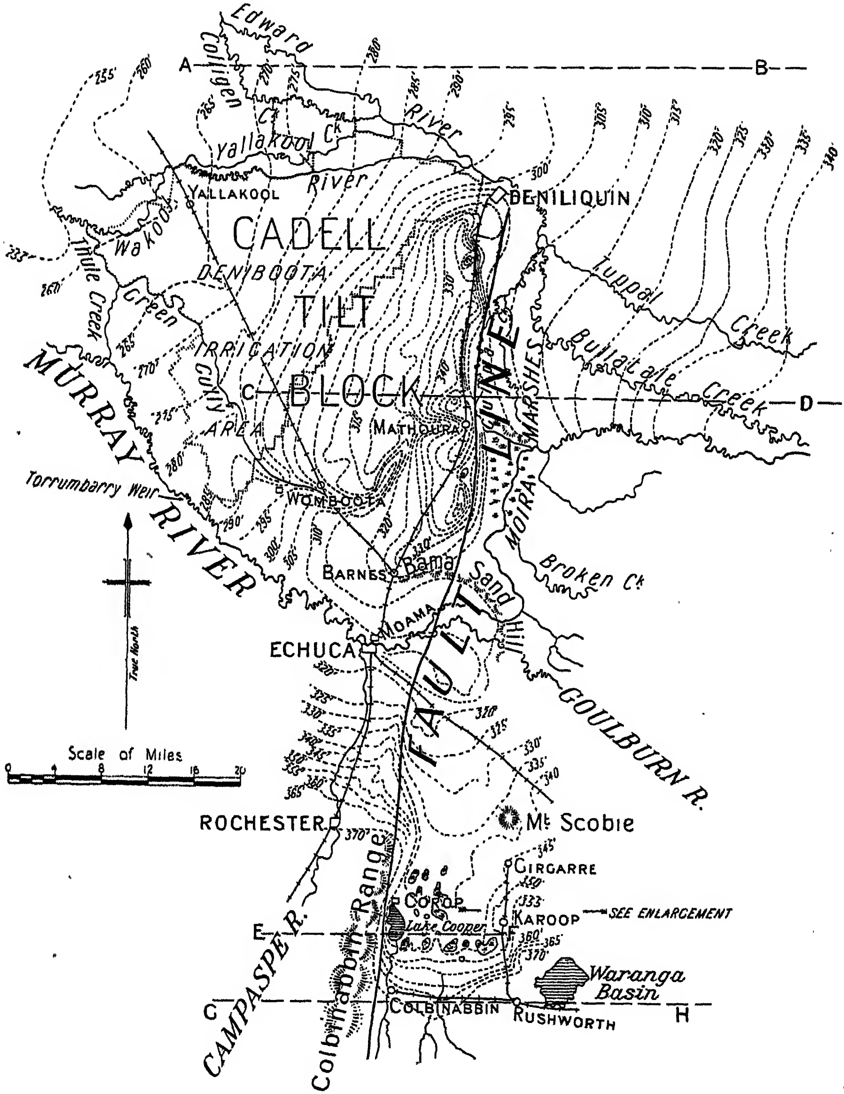


FIG. 1.

before actually entering it. North of the Murray the general direction of tributaries is from east to west and the Murray has numerous distributaries, some of which are permanent streams, while others flow only after the level of the main river has been raised by heavy rains or the melting of snow on the hills around its sources. The general direction of the contour lines in Victoria is east-west and in New South Wales north-south. In Victoria the general direction of these lines is broken by the presence of old rocks forming low hills between the various tributaries. Thus besides the hills which divide the upper Murray or Indi from the Mitta Mitta and the Mitta Mitta from the Ovens, we have the granite and Ordovician hills of which Futter's Range is the most prominent separating the Ovens from the Broken River, a spur of Silurian and older rocks between the Broken and Goulburn Rivers, culminating in the diabases and associated rocks of the Dookie Hills, the Colbinabbin Range between the Goulburn and Campaspe and the granite masses of the Terricks, Pyramid Hill and Mount Hope between the Campaspe and the Loddon. A minor spur runs parallel to the Colbinabbin Range but further east and is important for our present paper as it forms the eastern boundary of the Lake Cooper drainage basin. It is composed of the Silurian hills of Rushworth and is represented about sixteen miles further north by the isolated hill of Mount Scobie, also probably Silurian, which rises like an island above the level of the surrounding plains.

Several striking features break the regularity of the Murray plains :—

(1) The Murray River, east of Mathoura (N.S.W.), gives off two important distributaries to the north—the Edward River and Gulpa Creek—and then at the "Mathoura Bend" turns to the south as a stream of altered character till it approaches the Goulburn when it again takes a westerly course.

(2) West of this north-south reach and of the Gulpa Creek which continues the line to the north is a raised area 30 feet and more above the streams and sloping gently to the west. Not a single stream crosses it.

(3) East of the edge of this "Cadell Tilt-block" is an area of swamps and lagoons, interspersed with low sand ridges—the Moira Marshes—through which the Murray flows.

(4) South of the Murray the drainage from a large area between the Campaspe and Goulburn Rivers fails to establish a definite drainage channel to the Murray, and collects in Lake Cooper and its associated swamps making its way to the Murray in wet seasons either through ill-defined water courses or through artificial channels.

(5) Between the Lake Cooper area and the Campaspe River the Colbinabbin Range runs from south to north forming the western boundary of the Lake Cooper basin, which is separated

from the Goulburn basin to the east by the Rushworth Hills, and, further north, by a divide rarely recognizable in the field.

V. The Cadell Tilt-Block.

This name is applied to the triangular area of land between the Edward and Murray Rivers, the eastern base rising from the Murray River and Gulpa Creek, the southern side bounded by the Murray below Echuca and the northern by the Edward River and ana-branches which meet the Murray round the apex to the west

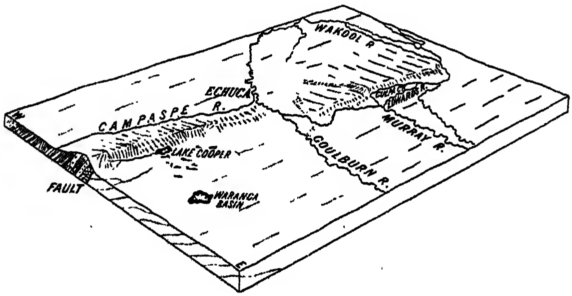
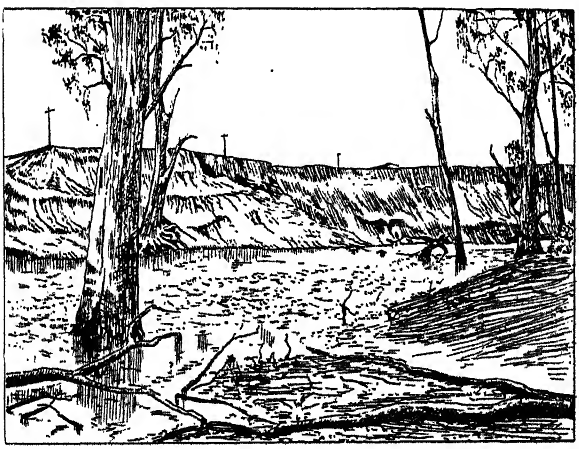


FIG. 2.—Block diagram of Area.



E. S. Hills Photo. *E. D. Service del.*

FIG. 3.—Culpa Creek south of Mathoura, showing steep bank on the western side.

From Yarrawonga to a point a few miles east of Mathoura the Murray pursues a general westerly course. It is very tortuous and cut-off meanders in all stages of evolution may be noticed. A good example is "Nine Panel Bend," a few miles upstream from the offtake of the Edward River. The "nine panel" refers

to the length of fencing necessary to cross the narrow neck of land round which the river meanders. At Yarrawonga and Tocumwal the critical stage of flood level of the Murray is over 20 feet above the cease-to-flow level. Below Tocumwal cuttings through the right bank of the river divert water into the Tuppal and Bullatale (locally Bullatella) Creeks, which ultimately join the Edward River near Deniliquin. As the little settlement of Tarragon is approached the banks of the Murray become lower and outlets through them, though small, become more numerous. At last, just east of Tarragon, a large channel, though small compared with the Murray, breaks out to the north, doubling back somewhat as it leaves the parent stream. This is the Edward River. It widens into a sluggish stream as it flows north, and at last turns west-north-west around the northern edge of the Cadell Tilt-block. The distance from where it leaves the Murray to its most northern point near Deniliquin is about 30 miles in a straight line. About a mile downstream from the Edward off-take the Gulpa Creek also leaves the Murray. At first its banks are steep and its channel deep, narrow, and canal-like. Then it expands into the Gulpa Swamp, and for about 4 miles it has no defined channel other than a shallow artificial cutting through the centre of the swamp. Near Mathoura it again becomes a wide muddy shallow creek with low ill-defined eastern banks, but steep, in places vertical, western banks (Fig. 3). After a tortuous northerly course it joins the Edward south of Deniliquin.

From the off-take of the Gulpa to the Mathoura Bend the Murray is still tortuous, but its banks are low, and the variation between high and low water levels throughout the year would be about 10 feet. Although the banks are low, floods rarely cover them continuously, and the even level of water throughout the year permits the growth of willow trees along the banks, making of these reaches a beauty spot.

About 2 miles west of the Gulpa off-take the Murray swings to the south. For over 20 miles it retains its low banks, but is narrow and comparatively straight. From its narrowness and shallowness the stretch between the Gulpa and Barmah is known to rivermen as the "little river." It is bordered by swamps which receive water through numerous small breaks in the bank of the river. The larger swamps, though shallow, may retain water throughout the whole year, and are known as the Moira Lakes both on the Victorian and New South Wales sides. Near Barmah the river regains its earlier character and turns west towards Echuca, being joined by the Goulburn River 7 miles east of the town.

The area between the Murray and Edward Rivers, as has been already stated, is crossed by no streams. The surface soil is a yellowish loam or clay though there are areas of grey loam

and some sandy rises. Its present undulating surface is partly due to modifications caused by rain wash, but there are well-marked tortuous depressions with a general east-west direction. The best-marked of these is shown on the map, trending south-west from near Mathoura, then north-west past Womboota, and ultimately merging into Thule Lagoon which is connected with the Murray. Where this depression is best shown it is a wide shallow valley with relatively steep sides, and with every appearance of being a disused, partly infilled river course. It is known locally as Green Gully.

The 350-ft. contour line runs along the eastern edge of the Tilt-block through Mathoura where the uplifted block reaches its greatest height—over 360 feet above sea level. The general height of the eastern edge of the block may be taken as 340 feet. Upstream along the Murray the 340-ft. contour line crosses the river near Tocumwal, 30 miles east of Mathoura. At the western edge of the Tilt-block the height is about 260 feet. The discussion of the significance of these features is postponed till later in the paper.

VI. The Moira Marshes.

The area between the Bullatella, Gulpa, and Murray, and the corresponding area on the Victorian side of the Murray is a region of sand ridges and swamps though there are considerable areas of relatively high land with a loamy soil. The numerous creeks are sometimes bordered by narrow banks above flood level, but on the other hand often widen into swamps and form a maze through which only an experienced bushman can find his way. The sand ridges are striking features in such country and seem often to be independent of the present drainage system. They will be briefly referred to later. Many of the swamps are apparently deserted stream courses, but others are wide expanses such as the Moira lakes which represent the lowest portions of a depressed area.

VII. The Colbinabbin Range and Lake Cooper.

The Colbinabbin Range stands out prominently on the geological map of Victoria, its colour, green for Heathcotian, showing up distinctly. The published maps show it as ending east of Elmore, but this is incorrect and mss. corrections are shown on some old maps. The rocks of the range may be traced on the low hills for some miles further north and are buried below the surface soil of the plains east of Rochester.

The geology of the range is not important for our purpose but as no account of it has yet been published, except for the part near Heathcote, a very brief summary of the geology of the northern part may be given.

The core of the range consists of diabase and cherty shales placed by Thomas (3), who has studied these rocks near Heathcote, as Middle Cambrian or older. On the west between Elmore and Colbinabbin (west of Allot. 122, Runnymede) shales yielded spicules of Protospongia (Harris and Thomas). These are the only fossils yet found in the area. Along the western side of the range fine-grained mudstones and cherty shales predominate, apparently of the Goldie Series (Upper Cambrian) of Thomas (3, p. 92).

These are well shown in road cuttings near Allots. 119, 130, and 206B, Corop, and in the north-west of Allot. 174, Nanneella. The diabase core of the range is in places massive and undecomposed as around Mount Burramboot (Allots 1, 5, Burramboot, and 40, Colbinabbin). The slopes of the range west of the Burramboot East state school show (quarry in Allot. 23, Burramboot and west of this) a succession of interbedded cherts and diabase, the latter being little altered on the hill slopes, but weathered to a greenish clay in the quarry. Near by, fragments of what may originally have been ash can be found. Jasper is a common associate of the diabase and is well shown along the north-south road between Allots. 63 and 65, Corop, and in the extreme north-west corner of the Parish of Burramboot. Fragments are common at other localities as in Allot. 7B, Corop.

The eastern slope of the Colbinabbin range is much steeper than the western and, lying about 2 miles east of the crest and 200 feet or more lower, is Lake Cooper, a shallow sheet of brackish water about 4 square miles in area. It receives the drainage of the Cornella Creek from the south but has no permanent outlet. It is only the largest of a number of similar depressions, most of which dry up in summer. In winter and after a succession of heavy rains the water level in Lake Cooper rises but most of the surplus water, instead of overflowing to the north, takes a parallel course east of the lake through an ill-defined series of swamps, and finally reaches the Goulburn or the Murray through channels partly natural and partly artificial. In fact the present drainage is regulated largely by a series of channels cut for the purpose. The Wanalta Creek further east uses the same intermittent drainage channels but has no lake along its course. It is a coincidence that the creek flowing into Lake Cooper is the Cornella (on some maps, Corneela), the main flood channel is the Cornelia Creek, while just across the Murray are Coronalla parish and Cornalla or Canally Station—all probably variants of the same native word.

The eastern boundary of the Lake Cooper-Cornella Creek depression is the "Rushworth Pene-plain" of Silurian rocks. Due north, rising as a hummock from the level and swampy plain is Mount Scobie, a low sandstone hill on which the writer obtained a few indeterminate corals, crinoid and brachiopod fragments which enable one to place it as almost certainly an outlier of the Rushworth beds.

North-west of Lake Cooper the edge of the higher country is represented very accurately by the main Waranga-Mallee irrigation channel which, through the mapped area, runs between the 375- and 365-ft. contours till it crosses the Campaspe River north of Rochester. Even further north, to within 5 or 6 miles of Echuca, the western edge of the depressed area is noticeable from the contour lines, which for over 10 miles north of the Waranga-Mallee channel near Rochester still run north and south and close together though showing a slope of only 10-20 feet. The wider divergence of these lines immediately to the north-east of Rochester is due to the fact that the Campaspe River breaks out across this stretch of country in flood time, using the Cornelia Creek channels for its surplus water.

VIII. Origin of the Lake Cooper Drainage Basin.

The swamps around and including Lake Cooper may be divided into two classes. Most of them, including Lake Cooper itself, occupy the lowest parts of the drainage areas of creeks flowing from higher ground further south—depressions which the water must fill before it finds its way further north—but some cannot be explained in this way. In the north-west of the Parish of Carag Carag and the north-east of the Parish of Corop are depressions which receive only local drainage but which are noticeably lower than the general level of the surrounding country. The best marked of these depressions are the Salt Lake, Green's Swamp, and an unnamed group of swamps in Allots. 38-40 and 50-53, Carag Carag. These are seemingly not connected with the main drainage problem, and the theory now to be advanced to account for the formation of the whole depression is strengthened by the existence of these isolated areas 20 feet or more below the general level.

It is suggested that two causes have operated in forming this region. Firstly, it is postulated that there has been down-faulting in recent times of the area east of the Colbinabbin Range. No direct evidence of faulting is visible here though further south near Heathcote faulting has been an important factor in determining rock relationships. There is no evidence that any of the Heathcote faults are recent; in fact most of them are geologically old and have no physiographic effect saving that which arises from the unequal hardness of strata. However near Bendigo (4) and west of Guildford (5) comparatively recent movement has been demonstrated to have taken place along old fault lines.

The unsymmetrical slopes of the Colbinabbin Range, as shown in the section (Fig. 6), and the low level of Lake Cooper and its drainage basin, as compared with both the Campaspe on the west and the Goulburn on the east, seem to point to factors other than normal erosion. The Campaspe at Elmore is 430 feet above sea level, the Goulburn to the east is 384 feet, while the swamps

around Lake Cooper are at 340 feet, the surface of the lake a few feet lower, Salt Lake at 320 feet (and isolated) and the general

MAP OF AREA AROUND LAKE COOPER

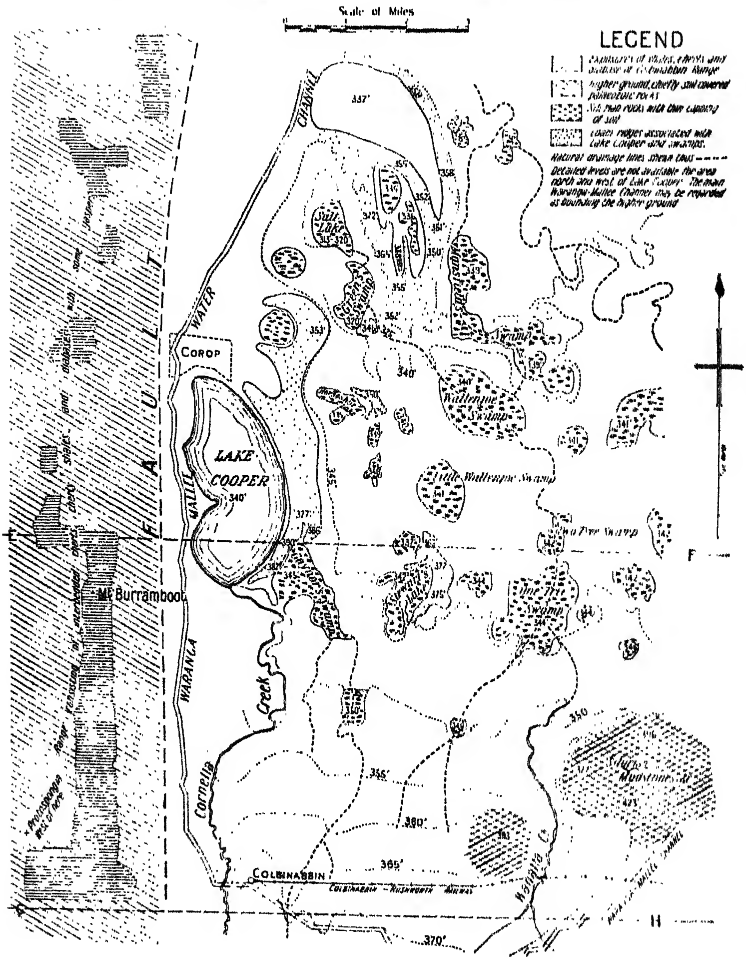


Fig. 4.

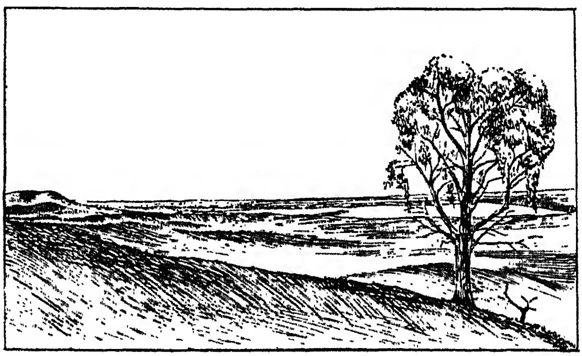
level of the surrounding plains between 340 and 350 feet. Lake Cooper is thus about 100 feet below the level of the Campaspe River at Elmore.

The physiographic features just described both south and north of Echuca can be explained if a south-north fault is postulated as running from west of Lake Cooper north to Deniliquin. In the south the result was the down-faulting of the Lake Cooper basin by perhaps 50-100 feet or even more. In the north the

Cadell Block was raised and tilted downwards to the west, the throw of the fault here being rather less than further south. Near Echuca where the movement hinged, as it were, there was little displacement and so the water of the Murray was enabled not only to find its way round the north of the raised block, but also to find its way round the south. For purposes of reference this fault may be referred to as the Cadell Fault. North-south faults are of common occurrence in northern Victoria, and at least in the two cases already mentioned—the Whitelaw fault east of Bendigo and the Muckleford Fault west of Guildford—recent movement along such a fault line seems proved. The present case would be a third example of this.

IX. Swamps in the Lake Cooper Depression.

While faulting is probably the chief agent in forming the Lake Cooper depressed area it does not fully account for some local features. These are depressions surrounded by loam ridges and not connected with the main drainage system. The best examples occur north-east of Corop. To examine this area the Corop-Stanhope road may be followed for about 3½ miles east from Corop, and a turn north then made between Allots. 93 and 94, Carag Carag. A shallow channel from the Wallenjoe Swamp



W. J. Harris Photo. *E. D. Service del.*

Fig. 5.—Lake Cooper from Colbinabbin Range, Mount Burramboot on extreme left (looking north-east).

crosses the road and, running to the north-west, enters Green's Swamp through a gap in a loam ridge. The ridge on either side of the gap rises to a height of 30 feet or more above the general level. The gap is steep-sided, but why a stream should cut such a gap is not evident since the swamp it drains had apparently another and easier outlet to the north-east. Following the road north one crosses the loam ridge which here bifurcates, one branch running to the north-east and the other slightly west of north. After the ridge is crossed a descent is made to an enclosed depression which contains three small swamps. These are merely

the lowest portions of the depression and derive their water from the surrounding slopes. The road passes through the centre of one swamp and, among the material ploughed up to form the road, may be seen nodules of earthy limestone. The presence of these nodules suggests that the actual position of the swamps may have been partly determined by the removal of limestone from the subsoil by solution. and the consequent sinking of the surface. Similar nodules occur round Lake Cooper itself and also around Salt Lake, and in other parts of the district.

The loam or clay ridges are difficult to explain and no satisfactory explanation occurs to the writer. The ridges rise to a height of 50 feet or more above the depressions in some cases, and are not composed of sand but of a yellow or brown clayey loam which when dry crumbles easily, but when wet would form a sticky mass. In addition to those already referred to an almost semicircular ridge flanks the eastern edge of a swamp in Allot. 107, Corop. (This swamp when dry is a practically level area of brackish silt.) The best marked ridge flanks the eastern edge of Lake Cooper (Fig. 4). It may be that these ridges are composed of silt blown from the depressions by west winds during a former long arid period, but this explanation does not seem fully satisfactory. The presence of remains of large trees in the bed of Lake Cooper, especially in the northern part, would indicate that the lake, if not formerly dry altogether, must for long periods have been smaller than at present, but since white settlement in the district a hundred years ago it seems to have contained water in most years. When E. M. Curr first traversed its bed in 1841 he described it as a grassy plain of wild carrot (2). P. Chauncy, in a letter to Brough Smyth dated 1873, brought under my notice by Mr. W. Baragwanath, states that he saw the lake dry in, he thinks, 1858, but his mention of this one instance would imply that this was very unusual. Old residents state that oat crops have been sown on the lake floor, and there is a report that it was dry about 1930. Large dead red gum trees (Eucalyptus rostrata), not yet stripped of small branches, are also found in the present channel of the Edward River east of Mathoura. A study of the lakes and associated loam ridges of the Kerang-Swan Hill district may throw light on the origin of the Lake Cooper ridges. Apparently similar silt hills are found on the southern and eastern sides of many of the shallow lakes in the Camperdown district, and are mentioned in Memoir No. 9 of the Geological Survey of Victoria. They are explained (p. 9) as being formed by silt blown from the dry beds of these lakes in summer. The explanation given there of the enlargement of Lake Colongulac may apply to Lake Cooper.

The Salt Lake occupies the lowest part of a depression even lower than Lake Cooper, and with a barely perceptible slope. The amount of brackish water varies according to the season, but the slope is so gentle that a sample of water free from mud cannot be

obtained without wading into the water. The shores of the lake are littered with fragments of earthy limestone as already mentioned, so that it is feasible to suppose that in this and other cases the actual position of the deepest portion of a depression may have been determined by solution. Like Lake Cooper, Salt Lake was probably often dry till irrigation channels were made through the district.

X. Sand Hills and Gravel Deposits.

Insufficient work has been done on this subject to warrant a lengthy discussion. The following facts may be stated:—

(1) Gravel deposits apparently derived from granitic rocks and not thoroughly waterworn occur at several localities, the best-known in the Echuca district being about 2 miles north of Moama, the New South Wales township on the opposite bank of the Murray to Echuca. This particular deposit is roughly stratified, and is comparatively free from iron staining. It may represent the partially re-sorted capping of a buried granitic mass such as Mount Hope or Pyramid Hill. As far as can be ascertained its thickness has never been proved by boring, possibly because the deposit, which is used for road-making purposes, could not be worked profitably below the level of the water in the Murray near by. Similar gravels, usually ironstained, are found in many places along the Murray, but are usually limited in extent, and most likely are coarse river-gravels. I have heard it stated that a bore a few miles south of Mathoura bottomed on granite at a depth of possibly 200 feet or so, but I have been unable to verify the statement which in itself does not seem at all improbable.

(2) Sand hills of much finer iron-stained material are widely distributed. They are antecedent to the present drainage system and are possibly records of an earlier more arid period. The sand consists chiefly of small fragments of glassy silica and is evidently wind-borne. The evidence shows that these deposits are older than the present river courses as the Murray, Goulburn, and Campaspe all cut through sand-hills. The best-marked ridge is known as the Bama Sand-hill, a ridge which runs for about 7 miles in a generally easterly direction from near the Barnes railway station on the Echuca-Deniliquin railway to the Murray west of Barmah (Victoria). It there turns to the south, crosses the Murray into Victoria, and is continued across a depression near Madowla, and then across the Goulburn. E. M. Curr (2) marks the Victorian part of this ridge on his map as the "Towro Sandhill," and states that he had often speculated on the reason for its independent direction, but he gives no indication of his conclusions. The Bama Sand-hill is only the most prominent of a number of similar ridges, a second ridge being cut through by the Goulburn just before it enters the Murray, and a third being

cut by the Campaspe and Murray near Echuca. These sand hills are quite distinct from the Lake Cooper loam ridges. Before leaving this topic attention may be called to the sand ridge which flanks the northern edge of the Gulpa Swamp. (For such ridges to flank swamps is not at all unusual.) This is composed of similar material to the Bama Sand-hill, but is lower. It, too, seems to be older than the low-lying land which encloses it, and its continuation is possibly to be found in loamy ridges south and south-west of Mathoura. These, being on the raised side of the Lake Cooper-Cadell fault line, have been denuded so that the material exposed at the surface is a sandy loam rather than sand.

XI. Physical Features and Irrigation.

The structure of the area has determined the course of irrigation channels through it. The Waranga Basin, fed from the Goulburn River, commands the area in Victoria between the Murchison-Colbinabbin railway on the south and the Goulburn River on the north, but as the level of the Basin is shown as 388 feet above sea level, it will be seen that it was necessary to make the main western channel skirt the Colbinabbin Range, so that it runs almost due north from Colbinabbin to a point east of Rochester, and then turns once more west. Water from it is unavailable for the district west of the range and south of Rochester.

In New South Wales the Cadell up-lift makes irrigation impracticable by gravitation for any but limited areas of the western portion of the Cadell Tilt-block, but a scheme is at present being worked out by which a supply of water, diverted from the Murray River at Yarrawonga, will be led across the Edward River at Deniliquin and made available for the western and lower portion of the area. The eastern boundary of the proposed irrigation area roughly follows the 300-ft. contour line, but with the necessary fall. The scheme is known officially as the Deniboota Domestic and Stock Water Supply and Irrigation Scheme, the name being derived from the districts of Deniliquin and Womboota, though it would appear that only a small portion of the Womboota district will be in the irrigable area.

XII. Summary of Geographical History of the Area.

It is possible to construct a theory which will account for all the major geographical anomalies of the district, such as the Moira Marshes, the Cadell Tilt-block, and the inefficient drainage of the Lake Cooper region. The following is the suggested order of events.

(1) The Murray at an earlier period flowed west past Mathoura, probably just to the south of the township, and then across what we have called the Cadell Tilt-block. The depression

shown by the contour lines (Green Gully) marks this former course, and a detailed map would probably show minor tributaries and "lagoons" such as fringe the Murray at present. The large sand ridge north of the Gulpa swamp would be on the northern bank of this former stream and probably extended further west than it can be traced at the present day.

(2) Movement took place along a north-south line from near Deniliquin to somewhere near Toolleen (north of Heathcote) forming the eastern edge of the Cadell Tilt-block and the western edge of the Lake Cooper basin. It is probable that the changes were effected by a number of small displacements, possibly spread over a long period, and that the final result was that in the north the western block was raised and tilted rather than that the eastern side was depressed, as the Moira Marshes are not lower than the plains a few miles north of Deniliquin. In the south the result was the lowering of the Lake Cooper basin. Near Echuca there seems to have been little movement so that the Murray was able there to find its way across the fault line. The raising of the Echuca-Deniliquin block dammed back the Murray and formed the Moira Marshes. The Murray, faced with an obstacle right across its former course, divided, some of the water working to the north along the scarp till it found a way round in that direction, and some working to the south with the same ultimate result. The Edward, the Gulpa, and the "little river" would thus originate after the uplift. If the rainfall of northern Victoria averaged 4 or 5 inches a month the Moira Marshes would probably be converted into a shallow lake comparable with Lake George (New South Wales). That the area between Rushworth and the Colbinabbin range is a structural valley formed by sinking seems to be indicated by its low level. Even with a greater catchment and heavier rainfall it would probably be water-logged as the fall between Lake Cooper and the Murray at Echuca is only about 30 feet as compared with over 60 feet in the shorter distance between Rochester and the Murray along the line of the Campaspe. The surface of Salt Lake is practically at the same level as the banks of the Murray at Echuca.

(3) When the Murray flowed across the Cadell Tilt-block the Echuca-Koondrook stretch of the present Murray was possibly the lower course of its present tributary the Goulburn, though there is some evidence that the old Green Gully stream was joined by a large southern tributary west of Moira (New South Wales). As a result of changes of level the "little river" was formed, and the combined Murray-Goulburn then adopted the present main channel.

(4) The actual position of Lake Cooper and some of its associated swamps has been partly determined by the removal of calcareous material from the subsoil by solution, a process which led to local subsidence.

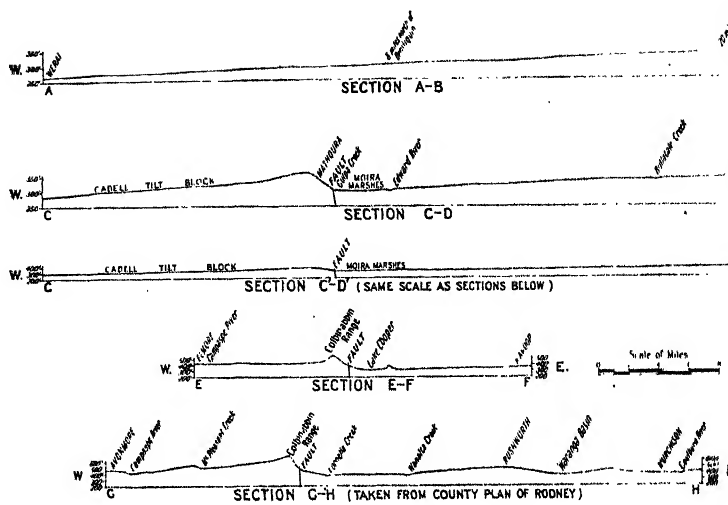


Fig. 6.—Profiles along section lines indicated in Fig. 1. All section lines are drawn to the same horizontal scale, but owing to the greater differences of elevation in the southern portion of the area the vertical scale of the two northern sections is greater than that of the two southern sections. For comparison Section C-D is drawn to both scales.

Section A–B.—This west-east section represents the general slope of Riverina north of the Edward River and beyond the influence of the Cadell Fault. The heights at both A and B are approximately the same as at C and D on the next section, but the slope is gradual and unbroken.

Section C–D.—Parallel to Section A–B but further south, showing the two similar slopes into which the general slope further north has been divided by the uplift.

Section C^1–D^1 is a repetition of Section C–D on the vertical scale used for the Lake Cooper sections.

Section E–F runs from Elmore across the Colbinabbin Range and Lake Cooper to the Rushworth-Girgarre railway at Karoop. The generally higher level of the western area, the drop to Lake Cooper, the loam ridge east of the lake and the featureless plain further east are shown. No figures are available for the height of the Colbinabbin range which is almost certainly higher than shown on this section.

Section G–H from Avonmore to Murchison has been drawn from heights recorded on the county plan of Rodney at approximately 1-mile intervals. Here again the height of the Colbinabbin range is underestimated as the plan gives heights along a road which passes through a gap in the range so that the highest reading on the plan is 1 mile west of the main ridge (626 feet). On the line of the range itself 588 feet is recorded, but the range is at least 100 feet above this. The difference in level between the eastern and western portions of the section is well shown. Near Rushworth Silurian rocks outcrop and the country rises generally.

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[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. I., 1938.]

Art. IV.—*Notes on the Physiography of the Geelong District.*

By ALAN COULSON, M.Sc.

[Read 9th June, 1938; issued separately, 23rd January, 1939.]

Introduction.

This paper discusses the following matters:—

(i) the altitude of the Otway Ranges in the Tertiary sea;

(ii) the post-Tertiary earth-movements and vulcanicity;

(iii) the development of the drainage system.

Altitude of the Otway Ranges in the Tertiary Sea.

The Jurassic rocks of the central portion of the Otway Ranges attain an altitude of 2,200 feet, and are flanked by marine Tertiary sediments of which the highest is about 900 feet. The Tertiary beds are limestone in the lower parts, and coarse sand in the upper.

This flanking relationship of the Tertiaries to the Jurassic was interpreted by Wilkinson (1865), Krausé (1874), Stirling (1901) and Hall (1911) to indicate that the Otways were an island of nearly 1,500 feet altitude in the Tertiary sea. Recently Hills (1935) has suggested that the Otways were completely submerged, and received a capping of Tertiary sediments, which was removed by denudation after the supposed post-Tertiary uplift. His objections to the earlier interpretation are:—

(*a*) absence of evidence of littoral facies in the Tertiaries;

(*b*) absence of evidence of existence of former shore lines;

(*c*) the deep dissection of the central portion of the Jurassics, which appears to be so vigorous as to indicate post-Tertiary uplift.

Regarding (*a*) it is true that littoral facies are rare in the Otway Tertiaries, though common enough in the parallel case of the Barrabool Hills, where the Tertiaries flanking the Jurassic have been shown (Coulson 1937) to contain pebbles of Older Basalt and (rarely) of Jurassic sandstone. The only instance of a boulder bed known in the Otway Tertiaries is at the base of the limestone of Alkemade's quarry, Kawarren, where a thin bed of Older Basalt pebbles can be seen. Three reasons may be advanced for the absence of littoral facies:

(i) the softness of the Jurassic gives a very short life to its detrital pebbles;

(ii) although the chances of Jurassic pebbles being included in the Tertiary limestone were fair, owing to the quiet water, they were remote in the case of the shallow-water Tertiary sands;

(iii) exposures of the contact between limestone and Jurassic are extremely rare, in fact, the author has not yet located one, whereas the contact of Tertiary sand and Jurassic can be seen at many places.

Regarding (*b*), the lack of evidence of the existence of former shore lines (this must also be admitted) and is more difficult to explain. The present shore line has characteristic rock-platforms, a few sandy pocket beaches at river mouths, occasional shingle beaches, and rare sea-caves. It is reasonable to suppose that similar features were developed at sea level in Tertiary times. Two possible explanations present themselves: (i) the sea-level in the Tertiary may have been steadily rising, as shown by the lithological change from limestone to sandy beds, and there may not have been a still-stand of sufficient duration to develop the features enumerated.

(ii) The features may have developed, and have since become obliterated by denudation. This is very likely on account of the softness of the Jurassic, and the rapidity of atmospheric and aqueous erosion in the area. Rock-platforms would become flat spurs, of which there are plenty in the ranges; the sand and shingle deposits of the beaches would be removed or obscured by vegetation, and the sea caves would in time collapse. Before the construction of the Great Ocean Road, several aboriginal shelter caves were known, but at the present time Ramsden's Cave (Hardy 1910) is the only one of any size above high water level.

Regarding (*c*) the deep dissection of the central portion of the ranges, the youthful appearance of the streams is due to rejuvenation by the post-Tertiary uplift, but, as will be shown later, they were initiated in Tertiary times when the Otways were an island.

A serious difficulty with the view of Hills is in the removal of the supposed universal capping of Tertiary sediments over the Jurassic. Such sediments would presumably be arenaceous like the present uppermost beds, and their thickness would be of the order of 1,500 feet. That every vestige of this great thickness of sandy beds should have been removed from the upper portions of the ranges is beyond belief; there would assuredly be large residuals of it, and the stream valleys would be choked with the practically indestructible detritus from the sand. But as is well known, the stream valleys in the higher Otways are singularly deep, steep-sided, and narrow, without alluvial flats. It is not

until after the 800–900 foot level is reached and the original Tertiary beds encountered, that the valleys widen out and become sandy. Clearly there never was a capping of Tertiary sediment over the Jurassic. Probably the marine sediments never exceeded the 900 foot level.

The theory of total submergence is therefore untenable, and the earlier view is retained here, that the Otway Ranges constituted an island in the Tertiary sea.

Post-Tertiary Earth Movements and Vulcanicity.

At the close of the Pliocene period and throughout the Pleistocene, the Geelong district suffered from a number of widespread shallow faults, and a few fold movements, and contemporaneous volcanic eruptivity on a grand scale. These processes have been dominant in determining the present topography.

It is probable that the general uplift of the whole area preceded the faults about to be described, and that it took place immediately at the close of the Upper Pliocene sedimentation. However, no great time interval elapsed before the faulting began, and probably differential stressing due to the uplift initiated it. The sketch map (Fig. 1) shows the main faults of the area.

FAULTS.

1. Rowsley-Anakie-Gheringhap fault.
2. Anakie-Lovely Banks fault.
3. Barrabool Hills-Curlewis fault.
4. Moolap-Leopold trough fault.
5. Corio Bay-Port Phillip Bay-Bass Strait faults.
6. Otway Ranges faults.

FOLDS.

1. Waurn Ponds Monocline.
2. Curlewis contorted beds.
3. Torquay and Anglesea anticlines.
4. Folding in the Otway Ranges.

1. *Rowsley-Anakie-Gheringhap fault.*

This pivotal fault commences in the Lerderderg district and extends 30 miles south through Rowsley and Anakie to Gheringhap. The maximum throw of 800 feet is at the northern end; it is about 500 feet at Anakie but disappears entirely near

Gheringhap. The fault has displaced Newer Basalt (Fenner 1918) of Pleistocene age, and is therefore late Pleistocene or even younger.

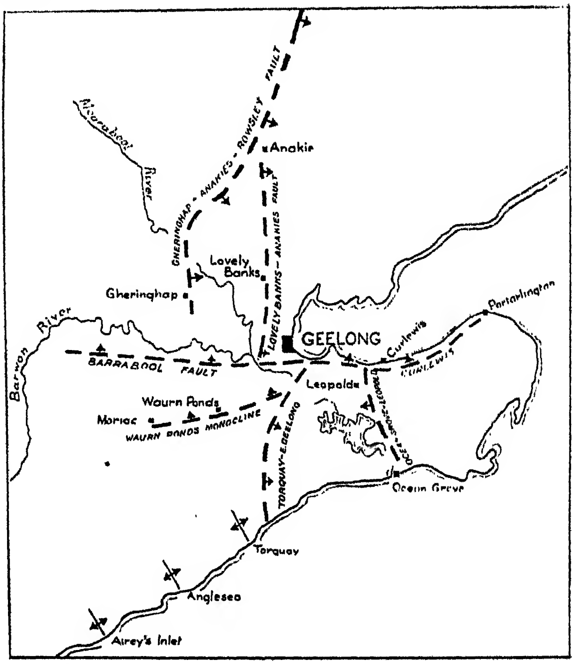

FIG. 1.—Faults in the Geelong District.

2. *Anakie-Lovely Banks fault.*

A normal fault commences at the central hill of the Anakies and extends nearly 20 miles south to near Fyansford Hill, running parallel to the Rowsley fault and about 5 miles to the east of it. The maximum throw of about 150 feet is in the middle section near Lovely Banks. Here again Pleistocene Newer Basalt has been displaced, the downthrow being to the east. The fault is therefore late Pleistocene or later.

3. *Barrabool Hills-Curlewis fault.*

The northern face of the Barrabool Hills is a demonstrable fault scarp, with a throw of 300 feet to the north near Ceres. The Barwon River flows along the fault line between Pollocksford and Fyansford. Originally noticed by Hall (1911), the fault was named the Barrabool Fault by Fenner (1918), and has been referred to as the Barwon Fault (Coulson 1930) but the prior name is here retained.

The western end of the fault begins near Pollocksford, and although the eastern end appears to be in Queen's Park, Fyansford, this is not the case, as the fault penetrates Newtown Hill and extends east to form the southern shore of Corio Bay, curving to the north-east near Curlewis and probably ending at Portarlington.

It is difficult to assign any age, other than post-Miocene, to this fault, as the only rock which can be traced on both sides of the fault plane is Miocene limestone near Gugger's Hill, Ceres (Coulson 1930). However, if we consider the youngest rock in the low cliffs on the southern shore of Corio Bay to have been fractured by the fault, this is the Pleistocene limestone (Pritchard 1895) of Limeburner's Point, and in that case the fault occurred in late Pleistocene or sub-Recent times.

A note may be inserted here regarding the existence of a fault between Batesford and Fyansford, postulated by some authors. Between these two places the Newer Basalt occupies two distinct levels; on the eastern side of the Moorabool River it is at 200–250 foot altitude, while on the west it is at 100 foot altitude. To account for the lower level basalt, hinge faulting has been suggested (Fenner 1918), the let-down block lying between two faults. The East-West Barrabool fault and a hypothetical North-South fault running from Batesford to Fyansford. The latter "fault" does not exist, as was proved in 1926 by the bores put down by Australian Cement Ltd. to test the thickness of limestone in their new quarry at Batesford. It was discovered that the limestone throughout the area tested was undisturbed, whereas if a fault had traversed it there would have been a displacement of 150 feet. The difference of level in the basalt flows is due to the fact that they are separate flows (Coulson 1937), the lower one filling a stream-eroded valley.

4. *Moolap-Leopold trough fault.*

Stretching from north to south between Corio Bay and the Connewarre Lakes is a flat strip of country, scarcely 10 feet above sea level, bounded on the east by the Leopold-Kensington Hill, and on the west by the East Geelong Hill. It may be called the Moolap sunkland. Bores in the sunkland (Coulson 1935) reveal much the same sequence as in the bordering hills, though of course at nearly 100 feet lower level. The structure appears to be a genuine trough fault, the bordering hills representing the former fault scarps. The western fault extended from Limeburner's Point south to Torquay, and the eastern from Curlewis to Ocean Grove. The Newer Basalt has been displaced, so the fault would probably be late Pleistocene.

5. *Corio Bay-Port Phillip Bay-Bass Strait faults.*

The southern shore of Corio Bay has been proved to be the eastern extension of the Barrabool fault. The bay has a depth of about 30 feet in most parts, but becomes very shallow on the northern shore near Corio and Avalon. It is probable that there is no actual fault on the north side, and that the bay was formed by tilting towards the south. In this case, the short section of cliff at the extreme western end of the bay, between Western Beach and North Shore, must be a minor fault scarp, running north-south.

Corio Bay is, of course, only the western extension of Port Phillip Bay, the origin of which is attributed to faulting, with the maximum throw on the east side along Selwyn's fault. This paper is concerned only with that portion of the faulting which delimited the Bellarine Peninsula. Presumably there was a small fault along the coast from near Portarlington past St. Leonard's to Queenscliff and Point Lonsdale.

Little is known of the foundering of Bass Strait, but it is reasonable to suppose that the faults along the Victorian coast were parallel to the present shore line, and probably not far from it.

6. *Otway Ranges faults.*

Recent field work by the author in the Otway Ranges has shown that over about 80 per cent. of the area, the Jurassic rocks dip to the south-east at about 15°. There are about half-a-dozen small areas, however, where this direction of dip does not hold. These are shown on the sketch map (Fig. 2). Unfortunately the field work is not yet advanced to the stage of plotting the numerous faults which have produced these tilted blocks in which the dip differs from the normal. There is no evidence of age available at present.

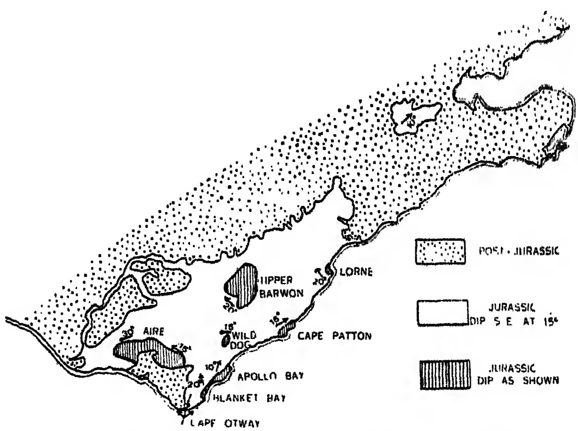

Fig. 2.—Areas of abnormal dip in the Otway Ranges.

FOLDS.

1. *Waurn Ponds Monocline.*

A downwarp of about 60 feet to the north occurs in the Miocene limestone at Waurn Ponds, and runs E.N.E. for several miles until obscured by younger sediments, but probably extends across the hiatus of the Moolap sunkland to Curlewis, where there is a disturbed area. A flow of Newer Basalt from Mount Duneed crosses the monocline just west of the Waurn Ponds quarries (Quarter Sheet 28 N.E.) without notable diplacement, so possibly the monocline is a pre-basaltic feature.

2. *Curlewis contorted beds.*

The Tertiary beds at Curlewis beach and Clifton Springs have suffered from intense folding and minor faulting (Coulson 1933). The locality appears to lie at the intersection of several lines of weakness, viz., the Barrabool Hills-Curlewis fault, the Leopold-Kensington fault, and the extension of the Waurn Ponds monocline.

3. *Torquay, Anglesea, and Airey's Inlet folds.*

Open folds occur in the Tertiary beds exposed in the coastal cliffs between Lorne and Ocean Grove, with anticlinal structures at Airey's Inlet, Anglesea and Torquay, and synclines between. A gentle synclinorium has thus developed, and its origin must be discussed. Hills (1935) considers that the folding is due to the differential uplift of the Otway Ranges (and consequent lateral pressure). In this case, the folding should be most intense near the Otways, but actually it is greatest at Torquay. The folding is to be attributed to sagging in the geosyncline of the Tertiary sea, for we know that the Tertiary beds form a tapered series, thin in the north and west, and thickest in the south-east, where differential subsidence must have occurred. This folding would thus be contemporaneous with the deposition.

4. *Folding in the Otway Ranges.*

In the valley of the Wild Dog Creek about 6 miles from Apollo Bay there is exposed in a road cutting a small monocline in the Jurassic mudstones. It was originally noticed by V. Stirling (1901). At the extremity of Cape Otway, the Jurassic sandstones of the shore platform form a pitching anticline, the western leg dips north-west at 9 degrees, and the eastern dips north-east at 10 degrees. In the cliff just below the lighthouse there is a large fissure, which is apparently not connected with the anticline.

Both these structures appear to be local, and are probably due to sagging ot competent beds. Usually in the Jurassics, earth-movements have resulted in faulting, but there are some small folds such as those described.

Upper Cainozoic Vulcanicity.

Starting in Upper Pliocene times and reaching a maximum in the Pleistocene, numerous volcanoes exuded the huge quantities of lava necessary to form the basalt plains of the Western District and Werribee fields. The petrological aspects have already been treated (Coulson 1937). Here we must consider the relation between the volcanic activity and the faulting, and the effect of the lava flows upon the drainage system.

It is the common phenomenon to find that the basalt boulders apparently clothe the face of the fault scarp, and Fenner (1918) has exhaustively discussed the three possible explanations, viz.:—

(*a*) the basalt flowed over a pre-existing fault scarp and solidified on the slope;

(*b*) the fault developed as the basalt was flowing or still plastic, the two being contemporaneous;

(*c*) the fault was later than the basalt, and displaced it, but the shattered basalt remained as partly buried blocks on the slope.

In the Geelong district the third of these processes seems to have been operative, and most of the faults are therefore late Pleistocene or Holocene.

After the major uplift which brought the Tertiaries above sea level, and before the eruptivity, a level plain stretched between the highlands of Ordovician rock in the north, and the Otway Ranges in the south. The original streams had begun to traverse this plain, the upper beds of which consisted of easily eroded Pliocene sands. Then came the floods of lava, filling the valleys and later forming a smooth field of lava with a gentle slope to the south. Bores through this basalt sheet have revealed the courses of the deep leads (Hunter 1909), and also show that the lava is much thicker along its northern margin (200 feet) than it is on the southern (about 30 feet). The general trend of the drainage was unaltered, although numerous small lava barriers interrupted the streams temporarily, especially in the case of the ancestral Moorabool.

Development of the Drainage System.

It is probable that the present drainage system is engrafted on that of pre-Tertiary times, at least in a general sense. The south-flowing streams from the northern highlands of the Divide, and the north-flowing streams from the Otways, originally discharged into the central arm of the Tertiary sea, which extended from Birregurra to Shelford and from Maude to Geelong. After the major uplift, these streams united on the Tertiary plains, and owing to the prevailing south-easterly dip of about 5 degrees that the Tertiaries have, the combined stream became a consequent river, the ancestral Barwon. Discharge was increased owing to the rejuvenation of the headwaters in the Divide and the Otways, and permanent valleys established.

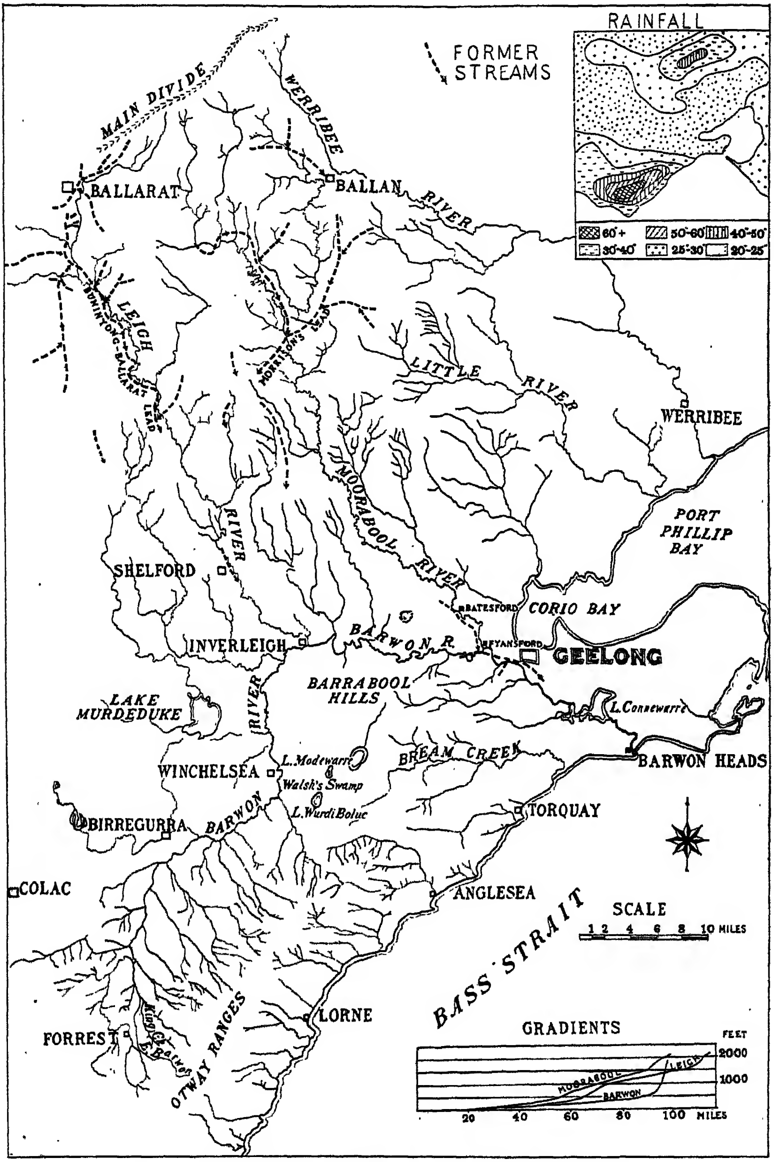

FIG. 3.—The Barwon–Leigh–Moorabool Drainage System.

The lava extrusions of the Newer Volcanic era did not materially affect the trend of these valleys, but led to entrenching and further rejuvenation. Relics of the basalt-filled valleys, shown in Fig. 3, occur at Durham Lead (Etheridge and Murray 1874), Shelford Lower Flow (Dennant and Mulder 1898), Morrison's Lead (Hunter 1909), She Oak Falls (Quarter Sheet 19, S.W. Note 2), and a hitherto undescribed flow extending from Batesford (Lower Flow) to Queen's Park, Fyansford, then through Newtown, Chilwell, South Geelong, Breakwater, and St. Alban's where it disappears beneath Recent sediments.

This flow fills a valley which was cut by the Moorabool River through the granite of the Dog Rocks, and extended south to Queen's Park where it junctioned with the Barwon at Buckley's Gorge. The former bank of this flow can be seen in Tertiary limestone exposed in a basalt quarry near Fyansford Bridge. The basalt-filled valley skirts the south side of Queen's Park at a high level, has been breached by the Barwon at Queen's Park Bridge, and crosses Newtown Hill to descend to Marnock Vale, where it received a small tributary from the direction of Highton, now seen as a residual on the east side of Prince's Bridge. This temporary barrier caused the formation of Harrison's Flats (terraced) on the west side of Prince's Bridge, and the accumulation of gravel and slate pebbles at Marnock Vale. There is no doubt that this stream was at one time the Barwon River, and it is important to remember its course when considering the former outlet of the river.

The present Barwon River rises from springs in the Otway Ranges near Mount Sabine, with tributaries starting at intervals along the north side of the main ridge towards Benwerrin. River capture has occurred where the former upper tract of the East Barwon is now occupied by the "big" King Creek (Gregory 1912).

Rich alluvial fans mark the debouchment of the Otway creeks on to the Tertiary plains. A bore at Barwon Downs showed 176 feet of sand and silt. Union of most of the tributaries is effected before Birregurra is reached; the river then proceeds to Winchelsea, where a right-angled turn takes it north to Inverleigh. Here it receives the Leigh River and reverts to its easterly course towards Geelong.

The right-angled turn of the Barwon at Winchelsea, was considered by Hall (1910) to be due to interference by basalt flows, from west of Winchelsea, with the original course of the Barwon, which, he said, coincided with that of the present Thompson's Creek (Bream Creek). This is a very tempting inference from the fact that a wide valley occurs between the Barrabool Hills and the Otway Ranges, partly filled with basalt,

and occupied by the insignificant Bream Creek. Closer examination reveals:—

(1) that the basalt did not come from "west of Winchelsea" but from a number of local vents, viz., a 550 ft. hill north of Wurdi Boluc, a 450 ft. hill near Winchelsea, Mt. Moriac, Mt. Duneed, and a hill near Pettavel, all rather local flows between which the river could easily have found its way;

(2) the Tertiaries between the valleys of the Barwon River and Bream Creek are the same height as the others of that locality, i.e., about 350 feet, and show no sign of a former deep valley having been filled with basalt;

(3) certain lakes in the valley, such as Lake Wurdi Boluc, Lake Modewarre, Walsh's Swamp, &c., which appeared to be remnants of a former large stream, have their beds partly in Tertiaries as well as basalt, and these beds are higher than the river level.

The supposed alteration of course is therefore not admitted, and the view is held that the Barwon always flowed to the west and north of the Barrabool Hills as it does at present, though possibly somewhat to the west of its present course.

Lake Murdeduke, west of the Barwon River between Winchelsea and Inverleigh, does not overflow to the Barwon. though some maps suggest that there is an outlet stream. A basalt ridge about 20 feet high separates the lake from the head of an intermittent creek which drains to the Barwon.

The Leigh and Moorabool Rivers commence as springs on the southern slopes of the Main Divide near Ballarat and Korweinguboora respectively and flow south, traversing Ordovician and Newer Basaltic rocks. Some waterfalls occur where the basalt flows have suffered headward erosion, e.g., at the Lal Lal Falls and the Moorabool Falls, or where lava barriers are encountered, as at the She Oak Falls.

Near Ballan the courses of the Eastern Moorabool and Werribee rivers approach very close, and Fenner (1918) considers that in pre-Newer Basaltic times both belonged to the Werribee system, the Eastern Moorabool later being captured by a stream which approached from the south.

A palpable error by Gregory (1912, p. 123) has left the widespread belief that the former mouth of the Barwon was in Corio Bay. The basalt which extends from Fyansford to Corio Bay was regarded by him as filling a former valley, but excellent cliff sections and road cuttings reveal that the basalt is part of a thin uniform sheet. From what has previously been said about the basalt-filled valley between Queen's Park (Fyansford) and Chilwell, it will be seen that the former Barwon always kept to the south side of the Newtown Hill, and entered the sea somewhere near its present mouth.

Conclusions.

1. The Otway Ranges constituted an island in the Tertiary sea.

2. Earth-movements of late Pleistocene age were responsible for most of the present topography.

3. The drainage system began in pre-Tertiary times, and engrafting took place after the post-Tertiary uplift.

4. The flows of Newer Basalt did not seriously interfere with the courses of the rivers. The Barwon did not flow along the valley of Bream Creek, nor was its mouth in Corio Bay.

Acknowledgments.

Thanks are due to the staff of the Geology Department, University of Melbourne; and to Messrs. G. B. Hope, W. Baragwanath, J. Easton, A. Mackie, J. B. Wilkie, and L. Coulson for assistance with the work.

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[PROC. ROY. SOC. VICTORIA, 51 (N.S.), PT. I., 1938.]

ART. V.—*Petrology of the Tertiary Older Volcanic Rocks of Victoria.*

By A. B. EDWARDS, Ph.D., D.I.C.

[Read 9th June, 1938; issued separately, 23rd January, 1939.]

Contents.

Introduction.

The general division of the Tertiary lavas of Victoria into an Older Volcanic Series (Miocene or earlier) and a Newer Volcanic Series (Pliocene to Recent) was introduced by the early Geological Survey of Victoria. The conception was based on the relationships of the lavas in the Port Phillip district to fossiliferous marine beds, and was then extended by "conjecture or analogy" to lavas in other parts of Victoria. The evidence for correlation often appeared slender or doubtful, and there was little to indicate "whether the Older Basalts (Older Volcanic Series) were contemporaneous or part of a series of eruptions extending over a long period" (39).

The detailed study of these lavas has barely been begun, but a representative collection from most of the outcrops correlated with the Older Volcanic Series is now available. The collection comprises about 300 thin sections of lava flows and about 350 sections of dykes. The specimens from which these were made were gathered chiefly by officers of the Geological Survey of Victoria, but notable additions have been made by Messrs. W. McCance, A. Coulson, and R. Jacobson, and the author.

Petrological examination of this collection makes it possible to advance from the position outlined by Professor Skeats in 1910 (39, p. 201), and present a more comprehensive study of this igneous suite. Since the Newer Volcanic Series has also been studied in considerable detail (12), it is also possible to make a precise comparison of the Older Volcanic lavas with those of the Newer Volcanic Series.

The Older Volcanic Series.

SUMMARY OF CONCLUSIONS.

For convenience of presentation, the conclusions arrived at in the petrological section of this paper are summarized here. The Older Volcanic Series is a distinct petrological suite comprised

of crinanites, olivine-titanaugite-dolerites, olivine-titanaugite-basalts, olivine-basalts, olivine-nephelinites, limburgites, and monchiquites, camptonites, and possibly acid differentiates in the form of tinguaites and phonolites. This association is closely comparable with the late Palaeozoic igneous suite in the west of Scotland (51), and also with the Tertiary "plateau magma" suite of Scotland (25). The probable composition of the Older Volcanic parent magma is similar to the Scottish plateau magma type, and corresponds to Kennedy's "olivine-basalt magma type" (26). This must not be confused with the "plateau basalts" of Washington (52), which constitute the "tholeiitic magma type" (26) of Kennedy, or the "non-porphyritic central magma type" of Scotland (25). No tholeiitic rocks appear to occur in the Older Volcanic Series.

It has been found also that the Older Volcanic suite is distinct from the Newer Volcanic, both in the nature of many of its rocks and in the probable composition of its parent magma. While the Newer Volcanic parent magma is also an "olivine-basalt magma type," it has some pronouncedly tholeiitic features.

The presentation of these results is the more apposite in view of a recent publication by Sussmilch, in which he states (50, p. 26) :—"The basalts of Victoria apparently belong to at least four distinct geological periods—(*a*) Oligocene, (*b*) Lower Miocene, (*c*) Lower Pliocene, (*d*) Pleistocene to Recent. Under these circumstances the use of the terms Older and Newer Basalts (i.e. Volcanics) is misleading, and has led to much confusion, and it would be better if both terms were dropped."

In making this statement, Sussmilch has placed too much emphasis on the "distinctness" of these four periods. They represent a continuous passage of time. He has also overlooked two features of volcanic rocks, one of which is a tendency to intermittent eruption over a considerable period of time; the other, that rocks from a common stock possess common characters.

As is shown in subsequent pages, the Victorian basalts are divisible, on petrographic grounds, into two fairly well-defined and widespread suites. One of these suites includes lavas of a pre-Miocene to Miocene age. The other includes lavas of a Pliocene to Recent age—in other words, they correspond to an Older and a Newer Volcanic Series. This being so, the terms Older Volcanic Series and Newer Volcanic Series are neither misleading nor confusing, but express clearly and adequately the conception of two periods of volcanic activity.

It seems possible that these two eras of volcanic activity were only maxima in a single great period, the extensive Older Volcanic extrusions dying away during the Miocene to a few minor extrusions, and recurring in the Pliocene after a period of rest and renewed differentiation, as has been suggested by Skeats and

Summers (45, p. 53). These two periods of intense activity must themselves have been diversified by fluctuations in intensity, and shifting of the centres of extrusion.

Distribution and Field Occurrences.

The Older Volcanic Series includes both lava flows and dyke intrusions. These consist of practically identical rock types, but in different proportions, and the distribution is somewhat different.

Lava Flows.

The rocks constituting the lava flows are crinanites, titan-augite-dolerites and basalts, several varieties of olivine-basalt, and minor amounts of limburgites and nephelinite, and possibly acid alkaline rocks. Their age relations are well established in the Port Phillip district, where they occur beneath fossiliferous marine beds of Lower Miocene age, as at Flinders (27), Balcombe Bay, and Grice's Creek (38), Royal Park (37), Keilor (8), and in the vicinity of Geelong (7, and references), or intercalated between such beds, as at Maude (7).

In South Gippsland the basalts pre-date the Tertiary faulting, and lie beneath the main seams of brown coal. This has been proved by diamond drilling at Warragul, Yarragon, Morwell, Boolara, and Welshpool. Stirling (49) and Herman (17) have shown that the deposition of the brown coals occurred intermittently over a considerably longer period than was required for the extrusion of the basalts, so that there are pre-basaltic, inter-basaltic, and post-basaltic brown coals. Thus, in Bore No. 1, at Yarragon, the following intercalation of brown coal and basalt was found (49, p. 74) :—

	Thickness of seam or lava. Feet.
Brown coal	17
Brown coal	24
Brown coal	67
Brown coal	8
Basalt	41
Brown coal	1
Basalt	45
Basalt	180
Basalt	70
Basalt	108
Brown coal	2

Similarly, at Leongatha, in Bores Nos. 3 and 5, seams of lignite, 6 inches and 9 inches thick, were found between basalt flows. The pre-basaltic and inter-basaltic brown coal seams are generally very thin, and never attain the great thickness of the post-basaltic brown coals. The most extensive development of brown coal beneath the basalts in South Gippsland is at Elizabeth Creek, in Allambee East, where there is a seam 40 feet thick while in the neighbourhood are seams 12 to 20 feet thick (49).

The brown coals of the Latrobe Valley are generally regarded as of Oligocene or Miocene age (38). Similar brown coals at

Parwan, Altona, Tyabb, Tanjil, and in East Gippsland underlie fossiliferous Oligocene or Miocene beds (4, 5), while at Hedley, near Gelliondale, brown coal is found beneath beds containing Pliocene fossils. On these grounds the basalts of South Gippsland should be Miocene or older. Sussmilch (50, p. 25) has claimed, however, that they "cannot be older than Lower Pliocene"; but in the same paper (50, p. 15) he arrives at the conclusions that the uppermost beds of the Yallournian (i.e. brown coal series) are possibly as young as Lower Pliocene, which would still make the basalts at least as old as Miocene.

At Dargo (33), Darlimurla (35), Narracan (3), Berwick (9), Pascoe Vale (34), Flemington (37), Beenak (24), Grice's Creek (38), Mahaikah (19), and Bacchus Marsh (32), the Older Volcanic basalts are found associated with Tertiary leaf beds. These leaves have been referred to the Miocene, but are not generally accepted as affording a precise indication of age. Nevertheless, the similarity of the leaf remains does suggest a broad contemporaneity for the lavas associated with them. At Berwick the leaf beds overlie a bed of brown coal from 2 to 3 feet thick.

The other lines of evidence as to the age of the Older Volcanic rocks, especially in East Gippsland, are the physiographic, which is described by Hills (18), and the petrological, given here. Correlation on petrological grounds tends to be regarded with suspicion, because rocks which originate by similar processes of differentiation must necessarily be generally similar in appearance and composition, even though formed at widely separated geological periods. It often happens, however, that a group of consanguineous rocks will possess minor peculiar characteristics which readily distinguish it from another generally similar suite. This is fortunately the case in Victoria, where both the Older Volcanic and the Newer Volcanic suites contain types with distinctive features and of widespread occurrence, viz., crinanites and titanaugite-basalts in the Older Volcanics, and iddingsite-basalts in the Newer Volcanics, as well as other less marked differences that are set out more fully in a later section (p. 92). Moreover, it has been found that classification of such rocks as Newer Volcanic or Older Volcanic by their petrological characters agrees closely with determination of their ages by physiographic or stratigraphic methods. The results of this classification by petrological characteristics, together with the data, are summarized in Fig. 1, which shows the probable distribution of the Older Volcanic lava flows in Victoria.

Dyke Intrustions.

The dyke swarms that accompany the Older Volcanic lava flows are comprised of crinanites, titanaugite-dolerites and basalts, olivine-basalts, monchiquites, rare nephelinites, and occasional camptonites, with possibly a few dykes of tinguaite and phonolite.

The age relations of these dykes are often obscure. At Kangaroo Gully, near Bendigo, they appear to be post-Permo Carboniferous (41). At Korkuperrimul Creek, Jacobson (20) has found several dykes of monchiquite and nephelinite which penetrate the earlier Older Volcanic flows, but either fail to penetrate the later ones or merge into them, so that there can be no doubt of their contemporaneity with the lavas. Equally definite relations can be observed in the neighbouring parishes of Gorong and Yaloak. Here the dykes in some instances penetrate the Older Volcanic basalts, but they clearly pre-date the Newer Volcanic basalts and the Tertiary leaf beds which the Newer Volcanic basalts overlie. These dykes are monchiquites, camptonites, and olivine-basalts, accompanied by a plug of olivine-nephelinite. Similar monchiquites and a nepheline-monchiquite occur further south at Anakies, and the You Yangs monadnock, and others presumably occur in the intervening country, beneath the Newer Volcanic basalts.

This swarm of dykes continues northwards, becoming dominantly monchiquitic with a minor number of camptonites, as far as Bendigo and probably Tarnagulla. Such dykes have been recorded from Steiglitz (15), Blackwood (14), Ballarat (16), Daylesford (53), Castlemaine (15), Maldon 15), and Bendigo (48).

No dykes occur in the Jurassic rocks of the Barrabool Hills or of the Otway Ranges, which are thus in striking contrast to the Jurassic hills in South Gippsland, where there is a strong swarm of crinanite, basalt, and monchiquite dykes. The western limit of the dyke swarm may be placed, therefore, between the You Yangs (and Curlewis) and the Barrabool Hills. A search through the literature reveals records only of diorite and acid lamprophyre dykes in the goldfields west of Ballarat, such as Beaufort, Scarsdale, Maryborough, Bealiba, St. Arnaud, Avoca, Stawell, and Wedderburn. The lamprophyres are in the main described as minettes, and seem to be contemporary with the diorites (i.e. probably Devonian), and so distinct from the Older Volcanic lamprophyres which are camptonites, sometimes grading into kersantites. An approximate western boundary of the Older Volcanic dyke swarm can be drawn from this data (Fig. 2).

In South Gippsland the dykes outcrop only in the upthrown blocks of the Jurassic, from which the Tertiary sands and brown coal have been stripped (10). They have been found in occasional diamond drill cores in the downthrown blocks beneath the Tertiary sands. They therefore pre-date the faulting of the region, like the lava flows, and since they are not recorded as penetrating the Older Volcanic flows, they are probably either earlier or contemporaneous with them. At Flinders, on the other hand, dykes occur in the basalts of the shore platforms.

In Eastern Gippsland there is no indication of the age relations other than that of petrological similarity. It is impossible to distinguish the crinanites, olivine-basalts, monchiquites, and camptonites that comprise the dykes of this region from those of the several areas previously referred to. A further line of evidence that supports the conclusion that all these dykes belong to the Older Volcanic Series is that the wide areas of Newer Volcanic rocks that have been examined seem to be practically destitute of dykes, despite many favorable exposures in stream sections.

As will be seen from Fig. 2, the Central Victorian dykes are dominantly monchiquitic with subordinate camptonites and basalts. Basalts become more prominent in the vicinity of Gorong, and are accompanied by occasional dykes of dolerite and nephelinite. East of Melbourne the basaltic dykes are increasingly predominant. In South Gippsland crinanites appear, and with olivine-basalts make up the majority of the dykes. The monchiquites are still numerous, and persist into Eastern Gippsland where they are joined by camptonites, phonolites, and tinguaites. The crinanites and olivine-basalts also persist into this region.

The full extent and strength of the Older Volcanic dyke swarms can only be conjectured. Heavy soils and vegetation obscure out-crops, and the dykes weather rapidly to considerable depths, so that generally they can only be observed in cuttings, stream sections, or mine workings. Mapping, moreover, has often been limited to rapid surveys.

The northern boundary of the swarm is equally a matter for conjecture. No Tertiary dykes are recorded in the north-east of the State, i.e., north and north-east of the Buffalo Mountains, Mount Hotham, and Glen Wills, although mapping in that part has been fairly detailed. Another hiatus occurs in North-west Gippsland. Tertiary dykes have been mapped in the Walhalla-Wood's Point belt (22, 28, 54), but none are recorded from further north. They have also been found at Warrandyte, Kangaroo Ground, and near Lilydale, but not further north. The mapping in this blank area has so far been of a reconnaisance character, so that dykes may well exist there. Still further north, however, where mapping has been more intensive, none have been observed, and since a number of dykes have been recorded in equally sketchily-mapped areas of Eastern Gippsland, they cannot be prominent in North-west Gippsland, and may not occur north of the tentative boundary suggested in Fig. 2.

Petrology.

The outcrops of Older Volcanic rocks about Port Phillip Bay, which undoubtedly underlie Miocene beds, were selected as the type Older Volcanics, particularly those of the Mornington Peninsula, which have the most extensive outcrop, and have been

explored by a number of diamond drill holes, the cores from which are available at the Mines Department. At Flinders one such bore was put down for more than 1,100 feet through a succession of basalt flows, while another at Cape Schanck penetrated about 800 feet of basalts.

The basalts in these areas contain abundant titanaugite and sometimes abundant analcite, combined with a relative absence of iddingsite, and are sometimes markedly ophitic in texture. They are distinct from the iddingsite-rich, titanaugite-poor basalts of the Newer Volcanic Series, but are identical with some of the dykes and volcanic necks of South Gippsland (10). These distinctive types are of wide-spread occurrence throughout Eastern and South-eastern Victoria, in association with other basalt types (Fig. 1), and serve as "marker flows" of a well defined petrological suite. Their presence among lavas of another area can be regarded as presumptive evidence that those lavas belong to the Older Volcanic Series, provided that there is no evidence to the contrary; and beginning with these types it has been possible to devise an approximate classification of the Older Volcanic Series into recognizable groups. In order to simplify subsequent discussion, local "type names," e.g., Keilor type, have been given to those groups which could not be given distinctive descriptive names.

Titanaugite Basalts.

Crinanites and Crinanite-basalts.

These doleritic olivine-analcite basalts occur in the lowermost flow of the Cape Schanck bore (700-850 feet), at Berwick (lower flow), at Kelly's Hill near Pakenham, at Gembrook, near Mardan, near Trafalgar, and at Narracan Creek (Allot. 125, Thorpdale), from Neerim to Noojee, at Leongatha, near Hallston, on the banks of the Latrobe River, north of Moe, and in diamond drill cores from the Dargo High Plains. They are coarsely ophitic rocks, and consist of a few embayed phenocrysts of olivine, which may be fresh or altered to serpentine, in a coarsely intergrown groundmass of plates of purple titanaugite up to 3 mm. across, and laths of labradorite (Ab_{35}-Ab_{40}) about 1.0-1.5 mm. long, coarse rods of ilmenite and needles of apatite, and interstitial analcite. The titanaugite sometimes encloses the olivine crystals. It is optically positive, with 2V about 60°, and pleochroic with X = purple-brown, Y = purple, and Z = yellow. Where it is in contact with analcite it may be altered to green aegirine-augite or even aegirine. The analcite is sometimes water-clear, but is more often cloudy and weakly birefringent. Flakes of biotite sometimes occur in association with the analcite and in cracks in the olivine. A finer-grained crinanite-basalt, showing flow arrangement in its groundmass, occurs at Warragul (Allot. 127).

These rocks cannot be differentiated from the crinanites which are so prominent among the north-west dykes of South Gippsland (10), and are probably co-genetic with them. No chemical analysis exists, but the composition must be closely similar to the analysis of the Gippsland crinanite shown in Table I., No. 1.

Ophitic-titanaugite-dolerites.

These differ from the crinanite-basalts only in the absence of analcite, and the minor amounts of aegirine and biotite. They occur at Korkuperrimul Creek, as the upper flow there (20), in the Dargo High Plain bore cores, at Upper Dargo, Cobungra, Mount Hotham, Mount Matlock, Yarragon, and on the Thomson River, and in the chilled base of the Neerim-Noojee crinanite, where it rests upon the Silurian. Similar rocks are found at Mallacoota and at Omeo as dykes.

Mooroodue Type.

A third group of closely comparable titanaugite-basalts occur in the Mooroodue bores (No. 8, 135-200 feet), Bittern bores (No. 2, 130 feet), Tyabb bore (No. 6, 404 feet), Flinders bore (No. 1, 0-99, 409, 536-671, 874-1135 feet), at Longwarry, in the Tangil bores at Bates Crossing (No. 4 and No. 7), Cape Schanck bore (No. 1, 43 feet), at Balnarring, Balcombe Bay, and San Remo, on the Bogong High Plains, in the bores from the Dargo High Plains, at Mother Johnson's Flat near Hotham, at Mahaikah, at Welshpool (bore No. 1, 440 feet), Toora (Allot. 15), at Berry's Creek, Mirboo (bore No. 20, 192 feet), in Devon (Allot. 103), at Maude, and at Russell's Bridge in the Geelong district, at the Korkuperrimul Creek, at Kangaroo Ground, Diamond Creek, and Greensborough, at Spring Plain, and Connor's Plain near Wood's Point, and at Flourbag Creek, Walhalla, at Livingstone Creek, and from a dyke in Collin's shaft near the junction of the Little Gibbo Creek with the Mitta Mitta. Similar dykes occur in South Gippsland (10).

These rocks are finer-grained than the previous groups. Olivine is the only mineral which forms phenocrysts. It may be fresh, corroded or, more frequently, altered to serpentine. The crystals range from 0.5 to 2.0 mm. in diameter, the smaller sizes being the more common. They are set in a medium-grained groundmass of violet titanaugite (2V about 60°), ophitic towards plagioclase laths (Ab_{40}), and abundant intersertal glass which is usually green, but sometimes yellow or brown. This glass is generally devitrified and birefringent, and is either chloritic or serpentinitic in composition (20). The degree of ophicity varies, as does the depth of colour of the titanaugite, and in chilled phases the pyroxene does not appear, but is replaced by an opaque glass which is packed with iron ore globules and is a purple or black colour. This glass resolves under high magnification into

a colourless base crowded with trichytes of iron ore. Such chilled phases are found at Tangil, Moorooduc, Flinders, and Tyabb.

A variant of this type is found at Korkuperrimul Creek, in the second lowermost flows of the Older Volcanic rocks of that district (20). The amount of green glass is diminished, and phenocrysts of titanaugite up to 3 mm. in diameter are present. The groundmass is coarser, and the unusually elongated laths of the plagioclase have segregated into sheaves. This feature is present to a lesser degree in a flow at Balnarring. An analysis of the Korkuperrimul rock is given in Table I., No. 4.

The specimens from Spring Hill and Connor's Plain, near Wood's Point, contain a greatly reduced amount of brown glass; and in specimens near Thomson's Bridge over the Latrobe (Narracan), and from half a mile east of Arthur's Seat, Dromana, and from Gembrook it is absent.

Iddingsite-Basalts.

Iddingsite-bearing basalts are relatively uncommon among the Older Volcanics, and such as do occur are readily distinguished from the Malmsbury and Footscray types of iddingsite-basalt so prevalent among the Newer Volcanics (12).

Iddingsite-titanaugite-basalts.

The basalt which occurs as a shore platform at Portarlington (7) is a typical titanaugite dolerite, except for the fact that the olivine crystals are heavily rimmed with red-brown iddingsite even when enclosed by titanaugite. Similar iddingsitization is observed in places in the olivine-titanaugite-dolerite which forms the uppermost flow at Korkuperrimul Creek (20).

The porphyritic variation of the Moorooduc type which occurs as the second lowermost flow at Korkuperrimul Creek, also grades locally into an iddingsite-titanaugite-basalt. The flows which overlie this rock are characterized by iddingsite (20), but this is accompanied by pale violet augite (2V about 60°) which is frequently pleochroic, and by varying amounts of clear green, yellow, or orange glass. The abundance of titanaugite in these rocks, and the type of glass mentioned in the last, readily distinguishes these rocks from the Newer Volcanic types of iddingsite-basalt.

Mirboo Type.

Iddingsite-basalts also occur in the Berry's Creek bore (No. 20) near Mirboo, where they form two flows, the uppermost (4th flow) and the flow at 117-147 feet depth (2nd flow); in the Flinders bore, as several flows (about 160 feet, 215 feet, 300 feet, 500 feet, and 850 feet levels); in the Cape Schanck bore; and at Evelyn.

These basalts are all fine-grained, slightly glassy rocks, consisting of phenocrysts of olivine slightly altered to iddingsite, set in a groundmass of plagioclase laths (Ab_{46}), granular to idiomorphic crystals of colourless or pale-violet pyroxene, iron-ore grains, and a variable amount of green glass. Numerous vesicles of chalcedony and glass are present in the Berry's Creek rocks, and in some slides a little biotite is present. The alteration of the olivine to iddingsite is of uniform extent, and pre-dates the crystallization of the pyroxene of the groundmass, since iddingsitized olivine crystals are frequently observed enclosed by aggregates of pyroxene. Small grains of iddingsite are present in the groundmass. The rock from the lower flow at Berry's Creek is a chilled phase, in which the felspar was unable to crystallize to any extent, so that it has the appearance of a limburgite.

The olivine cores may or may not be altered to serpentine. Such serpentine as is formed is often bright green, pleochroic to a yellow green. In the Flinders specimens the olivine crystals reach dimensions such as 3-4 mm. across, with a very thin rim of iddingsite, and in one of the higher flows at this locality the iron-ore forms coarse octahedra larger than the individual pyroxene grains.

In the Flinders rock from the 215-ft. core, the iddingsite is the yellow variety (36). It is strongly pleochroic and shows straight extinction. A vein of iron-oxide stained rock appears in the slide. As this vein is approached the yellow iddingsite makes over to red iddingsite. Chalcedony is again present as vesicles and veins.

The 4th flow at Barry's Creek has been analysed, and the analysis is shown in Table I., No. 9. The richness in magnesia is due to the presence of much serpentine, both pseudomorphous after the olivine, and as the green glassy base.

Olivine-basalts.

Associated with these more distinctive types of basalt are several other variations in which titanaugite is rare or absent.

Keilor Type.

A distinctive type of glassy olivine-basalt occurs at Green Gully, Keilor, below Lower Miocene marine beds (8), at Broadmeadows (47), along the Maribyrnong River at Essendon, at Cape Schanck (bore No. 1, 32 feet), at San Remo, and on Phillip Island.

It consists of microphenocrysts of slightly corroded fresh olivine, set in a groundmass of laths and microlites of plagioclase (Ab_{35}), minute grains of pyroxene, octahedra of iron ore, and abundant brown glass which constitutes over half the rock. The specimens from Essendon and Broadmeadows are identical except that an occasional phenocryst of (?) anorthoclase is present at the latter locality (47). The Cape Schanck and San Remo specimens

are rather more crystalline, so that the felspar laths are larger and the pyroxene grains larger and more numerous, while the amount of brown glass is less.

An analysis of the Broadmeadows flow is shown in Table I., No. 10.

Buckland Type.

An unusual type of basalt occurs as pipes and dykes in association with the phonolites and tinguaites of Harrietville. Rather similar rocks occur at Mt. Buffalo, Bogong High Plains, Sandy's Creek in the Tabberabbera district, and Cape Schanck. The dyke at Buckland Gap, near Harrietville, is selected as the type. It contains numerous phenocrysts of plagioclase, augite, and olivine, in a fine-textured groundmass. The plagioclase is labradorite (Ab_{45}), and frequently forms rectangular crystals. They are commonly corroded at the edge and at the core. The augite occurs as greyish-brown, idiomorphic crystals, sometimes 2-3 mm. in diameter. The cores of these crystals are sometimes pleochroic from pale green to yellowish-green. In other instances they are " spongy " with inclusions. Olivine crystals are smaller and less numerous, and are slightly altered to serpentine. The groundmass shows no fluxion structure, and consists of minute rectangular and lath-shaped crystals of labradorite, small grains of augite and olivine, and an interstitial base of minute grains of augite, iron ore, and glass. The other dykes and pipes of the district are similar, although the proportions of the phenocryst minerals vary.

In the rocks from Mt. Buffalo and the Bogong High Plains the proportion of plagioclase phenocrysts is greatly reduced, while the olivine and augite are more abundant, but often corroded. The augite has a marginal zone of titanaugite. At Sandy's Creek, on the other hand, phenocrysts of labradorite dominate. The Cape Schanck rock is closely comparable with Buckland Gap specimen, except that its pyroxene is a purple titanaugite. A somewhat comparable rock occurs at Grange Quarry, Double Creek, near Flinders, but here the phenocryts are solely of a brownish-violet augite, up to 2 mm. in diameter, and the fine-grained groundmass shows fluxion structure. No basalt of this type has yet been met with amongst the Newer Volcanic Series.

At Brandy Creek, near Mt. Bogong, a porphyritic type occurs in which idiomorphic phenocrysts of titanaugite, 10 mm. in diameter, are set in a medium-grained groundmass of corroded olivine, plagioclase laths, small crystals of violet augite, iron ore, and interstitial analcite, which shows weak birefringence.

Berwick Type.

Basalts of this group occur at Berwick, Bogong High Plains, Mt. Fainter, Mahaikah, Mt. Moreton (Belgrave), Korkuperrimul

Creek, Leongatha, Welshpool (Allot. 1 of B), Mt. Jim. and Battery Hill, Cobungra, and among the South Gippsland dykes. The type locality is the upper flow at Wilson's Quarry, Allotment 15 of Berwick.

It is a fine-grained olivine-basalt with microphenocrysts of olivine, more or less corroded, in a groundmass which shows little or no fluxion structure, and consists of olivine, pale violet to colourless augite granules, minute octahedra of iron ore, clear, colourless glass, and small but not very numerous laths of plagioclase (Ab_{35}). Between crossed nicols the rock has a characteristic appearance, small bright spots of olivine standing out in a black base which is flecked with minute, yellow spots (augite) and small grey laths of plagioclase. Rocks of this group are not easily distinguished from certain basalts of the Newer Volcanic Series.

At Berwick large phenocrysts of anorthoclase occur sporadically in the basalt. This feature is found in the Flinders type basalt at Aberfeldy (29), and also in a monchiquite-basalt at Moyarra (29).

Flinders Type.

This, the most widespread of the Older Volcanic basalts which does not carry titanaugite, occurs at Flinders (bore), Connor's Plain, Korkuperrimul Creek, Jindivick (Allot. 19), Grice's Creek, San Remo, Emerald, Mt. Hotham, Cape Schanck (bore), Royal Park, Alberton West (bore 92), Mooroodue (bore No. 9, 109-119 feet), Aberfeldy (Mt. Lookout and along the interfluve between the Thompson and the Jordan Rivers), Mt. Loch (Bogong High Plains), Ruby, Maude, Airey's Inlet, Curlewis, Sylvan, Leongatha, Warragul, Devon, Boolarra, Mt. Buller, Greensborough, Kangaroo Ground, Lilydale, South Buchan, White's Plain (Cobungra), 15 Mile Creek (Dargo), and among the dykes of South Gippsland (10).

Its characteristic feature is the presence of considerable amounts of green glass, generally devitrified, when it appears to be serpentine. It differs from rocks of the Mooroodue type in the absence of titanaugite and ophitic structure, but intermediate variations are to be found. Olivine is usually the only mineral occurring as phenocrysts. In some of the Flinders bore cores it forms crystals 2-3 mm. across, but it is generally smaller. The olivine crystals are nearly always corroded and partially altered to serpentine. Occasional microphenocrysts of brown augite and plagioclase accompany the olivine. Sometimes, as in one San Remo specimen, the plagioclase is more abundant. The groundmass frequently shows fluxion structure, and is an intergranular growth of pyroxene granules, laths of plagioclase (Ab_{40}), iron ore, and the intersertal green glass. The pyroxene varies from colourless to pale violet, when the rock grades into the Mooroodue type. The grain size is rather variable at different localities, and

in some instances the green glass is present in only small amount, or may be lacking entirely.

Rocks of this group are not readily distinguished from those of the Trentham type of Newer Volcanic basalt. Moreover, the distinction between the Berwick and Flinders type is based solely upon appearance in thin section. The two rocks are probably chemically similar, as is also the titanaugite-bearing Moorooduc type. Its difference from the Mirboo type is based on the absence of iddingsite, although the analyses (Table I., Nos. 5-8) suggest that the Mirboo type is rather more basic and richer in MgO.

Mugearites.

Mugearitic types are rare among the Older Volcanics, in contrast to their relatively widespread development among the Newer Volcanics. Only two occurrences are known—a pipe at Aberfeldy, described by Mahony (28) as an olivine-andesite, and a dyke on the Dargo High Plains. The felspar laths which constitute a large portion of the Aberfeldy rock are mostly oligoclase with cores of andesine. It undoubtedly belongs to this group, and should be called olivine-andesine basalt (or olivine oligoclase-basalt) rather than andesite. An analysis of the rock is given in Table I., No. 2, but there is some doubt as to whether the analysis quoted is really of this rock. Three analyses were made of the Aberfeldy basalts (Mem. Geol. Surv. Vict., No. 15, p. 44, Analyses 4, 7, 8). Of these, Analysis No. 4, reputed to be of the olivine-andesite, and Analysis No. 8, reputed to be a basalt, do not correspond with their respective thin sections. If, however, the analyses are interchanged, a very good agreement is found. It seems probable, therefore, that some mixing of the specimens has occurred. Accordingly, I have quoted Analysis 8 as representing the composition of the olivine-andesite.

Olivine-nephelinites, nepheline-limburgites and monchiquites.

Rocks of this character are known to occur at several places in the State, namely along Korkuperrimul Creek (20), at Greendale (42), at Drouin West (Allot. 91) (30), in the Bogong High Plains, and at the You Yangs(1). Only in the first of these occurrences is the age relation of the nephelinite beyond doubt. Jacobson (20, p. 134) has shown that at Korkuperrimul Creek there are several flows of olivine-nephelinite which grade laterally into nepheline-limburgites. They overlie flows of the Flinders and Moorooduc type, and are overlain by thin flows of limburgite and olivine-titanaugite-dolerite.

The Greendale occurrence is in the form of a plug intruding Permo Carboniferous glacial beds (42). Apart from its nepheline content, the plug resembles the Older Volcanic monchiquite dykes

of this district. The You Yangs occurrence is equally indefinite in age. It consists of a dyke with strongly monchiquitic affinities, accompanying monchiquite dykes which have invaded the You Yangs granite (1). It is probable that similar monchiquites intrude the surrounding Palaeozoic sediments, but are now hidden beneath the Newer Volcanic basalts.

The specimen from the Bogong High Plains is almost identical in appearance with that from the plug at Greendale, but is rather richer in nepheline. It was found by Mr. McCance, but was not in situ, so that its mode of occurrence is unknown. The other basaltic rocks of this area include definitely older Volcanic types.

The olivine-nephelinite at Drouin West, described by Mahony (30), is a plug surrounded by basaltic soil, so that its age is indefinite, although it appears to intrude the Older Volcanic lavas. This rock is a true nephelinite, and lacks the monchiquitic features of those from the other localities. It will be seen from the chemical analyses of Table II., Nos. 1-3, that the difference is expressed by the higher Na_2O content of the Drouin rock. The Korkuperrimul analysis is of a nepheline-poor variety of the type occurring there, and is therefore not truly representative of the soda-content of the olivine-nephelinites proper of that district.

Limburgites and Monchiquites.

Limburgites occur at a number of localities, but are not common as flows. The most extensive flows are in the Korkuperrimul Creek area (20), where they occur beneath basalts of the Flinders type, and above iddingsite-titanaugite basalts, and grade laterally into olivine-nephelinite. True flows or plugs occur at Euroa (? Newer Volcanic), Tommy's Hut, and Balwyn, and in the vicinity of Greendale. Other specimens in the collection are from Ensay, Broadford, the Basalt Temple on the Bogong High Plains, Mt. Hotham, Drumblemara (stone reserve), Mt. Deddick, Buchan (Allot. 10-18), the Buffalo Mountains (Crystal Brook), the Maude Mine at Glen Wills, the Blackwall Mine at Toombon, Harrietville (Rose, Thistle, and Shamrock Mine), Harkaway (N. of Berwick), and Parwan Creek (Yaloak). Most of these are from dykes, and they closely resemble the dykes of monchiquite in South Gippsland, Bendigo, Maldon, and Daylesford districts. In some instances they are clearly older than the Newer Volcanics, as at Yaloak and Greendale, but more often their relation is indefinite. However, it is to be noted that dykes appear to be rare among the Newer Volcanic lavas, although small flows are fairly numerous, as at Macedon, Woodend, Gisborne, Romsey, and Springfield (12). There is little, if anything, to distinguish between the limburgites of these two series petrologically.

Camptonites.

Dykes of camptonite are known to occur at Greendale, Daylesford, Bendigo (48), between Ensay and Jambarra, at Orr's Creek near Dargo, at Nedside on Livingstone Creek, and at Forest Hill, South Yarra.

The Greendale dyke intrudes the Ordovician in Dales Creek close to the plug of nephelinite, and is associated with dykes of monchiquite and olivine-basalt. It differs from the monchiquites in the presence of numerous microphenocrysts and wisps of brown hornblende and biotite, subordinate laths of plagioclase, and interstitial areas of felspar which may be anorthoclase. In this respect it is similar to the Bendigo camptonites. Some of the titanaugite crystals have cores of emerald green pyroxene which is pleochroic to yellow green, and appears to be aegirine. It differs from the biotite-lamprophyre at the freehold Mine, Daylesford, only by the absence of coarse crystals of biotite.

Slides of a similar rock from a locality called Ferntree Gully on the track from Ensay to Jambarra, were found in the Howitt Collection (in the Melbourne University). In these, however, the hornblende is restricted to numerous laths and wisps in the groundmass, and is accompanied by more aboundant biotite. Allied dykes in Orr's Creek and Livingstone Creek contain abundant crystals of brown hornblende and biotite. In the section from Livingstone Creek the hornblende crystals are frequently as large as 3 mm. in diameter, and are accompanied by titanaugite crystals of the same dimensions. The titanaugites, like those in the Greendale rocks, have cores pleochroic from deep green to greenish-yellow. No plagioclase occurs in these latter two specimens, however, so that they represent an intermediate stage between the camptonite proper and the monchiquites. The gradation from the other end, by the development of "ocellar" patches of sub-radiate hornblende laths and analcitic glass, has been noted in the dykes of monchiquite at Bendigo (48) and South Gippsland (10).

Acid Differentiates.

There has developed a tendency to regard all the Tertiary alkaline rocks in Victoria as belonging to a single Middle Kainozoic Alkaline Series, distinct from both the Older Volcanic and the Newer Volcanic Series (e.g. 50, p. 25). This is, however, a misunderstanding of the facts, which appears to have grown from a statement made by Professor Skeats in 1910, when referring to the difference in age between the Macedon dacites and the Macedon alkali rocks, namely: "The Alkali Series is a much younger one, of probably Mid-Kainozoic age, since the later rocks merge into the newer basalts" (Newer Volcanics) (39, p. 203). In the same paper he suggested that the similar alkali rocks in the Western District "may be of the same age as the Macedon

rocks" (p. 204), while in 1912 (45, p. 53) and 1914 (40), it was further suggested that a number of the isolated occurrences of phonolite, tinguaite, and solvsbergite might also be of the same age as the Macedon rocks.

It is unlikely, however, that all the Tertiary alkaline rocks in Victoria were extruded simultaneously, and in some localities there is proof that they were not. Petrogenetic studies of the Newer Volcanic Series in Central Victoria (12) have made it clear that the solvsbergites, trachytes, trachyphonolites, and trachyandesites of Macedon, Trentham, Tylden, Bullarto, Coliban, and Gisborne, are the typical acid-differentiation products of the olivine-basalt lavas with which they are associated, and the same seems to be true for the trachytes of the Western District. Such associations are characteristic of olivine-basalt provinces throughout the world (46), and are to be expected wherever conditions have permitted more or less complete "cupola differentiation" to take place (11, 13). The time most favorable to complete differentiation is generally that immediately preceding the beginning of extrusion. Subsequently the main magma reservoir is thought generally to have approached so close to the surface that further extrusion occurs before there is time for repeated advanced differentiation. Thus it is that the greatest development of alkaline types in olivine-basalt provinces throughout the world has been during the early stages of extrusion (46). The Newer Volcanic lavas of Victoria are no exception in this respect.

As indicated above, the alkaline lavas are pictured as centred above cupola-like protrusions of the main magma reservoir. Although in each locality in which they occur they will be among the early extrusions from that cupola, it is unlikely that all the cupolas of a province will develop at the same time and rate, so that there will be no definite period of alkaline extrusions. Moreover, if extrusion is interrupted for a sufficiently long period, renewal of differentiation within the magma reservoir may give rise to later alkaline rocks, as it has done at Coleraine and Casterton (40), and at Gisborne.

A feature of the Tertiary alkaline rocks of Victoria is that those which definitely belong to the Newer Volcanic period are predominantly trachytes or have trachytic affinities, while those which outcrop in Eastern Victoria, in proximity to the Older Volcanic lavas, are predominantly phonolitic or have affinities with phonolites. This may be a coincidence, but it assumes significance in view of the richness of the Older Volcanics in soda, expressed by the development of olivine-nephelinites, analcite-basalts, and crinanites, as contrasted with the relative richness of the Newer Volcanics in potash, as indicated by the

development of macedonites, mugearites, and woodendite. This raises the possibility that the isolated occurrences of alkaline rocks in Eastern Victoria may, at least in part, be acid differentiates of the Older Volcanic Series.

The alkaline rocks most likely to belong to the Older Volcanic Series are the pipes and dykes of phonolite, sodalite-phonolite, and tinguaite near Harrietville (42), which occur in association with pipes and dykes of olivine-basalt of the Buckland type. These pipes are from 50 feet in diameter, up to 20 acres in extent. The rocks composing some of them differ from the alkaline rocks in other parts of Victoria in that they contain numerous phenocrysts of basaltic hornblende which is reacting with the groundmass to form aegirine and iron ore. In a number of instances the brown basaltic hornblende, which shows straight extinction, remains only as a core to a deep green hornblende with an extinction angle of 20°. The alteration is transitional, so that there can be little doubt as to the sodic character of the green hornblende. This development of basaltic hornblende in phonolites, with subsequent alteration to aegirine, appears to be a characteristic feature of many phonolites and allied alkaline lavas. Its restriction to strongly differentiated types has led the author to suggest that it forms during the cupola stage of differentiation of a basaltic magma (13).

Other acid alkaline types which may belong to the Older or Newer Volcanic Series are a dyke of phonolite from Dargo flat (Howitt Coll.) (43), the phonolite and tinguaite dykes of Tabberabbera (44), the phonolites, tinguaites, trachytes, and solvsbergites of Omeo (40), the biotite-phonolite of Gallows Hill, near Mahaikah, in the Mansfield district (40), and possibly the trachyte-solvsbergite dykes and syenite of Mt. Leinster (2). This is, of course, purely conjecture, particularly since Newer Volcanic lavas occur in the region, as at Benambra and Gelantipy (18).

Pyroxenes.

No very definite statement can be made as to the composition of the pyroxenes. Approximate measurements of 2V were made (by comparison of acute bisectrix figures with such figures for minerals of known 2V; muscovite and aragonite) wherever possible. These gave values of 2V about 60° for the titanaugites, but in the basalts without titanaugite the pyroxene grains were generally too small for determination. Such measurements as were achieved gave values of 2V of about 50–60°, and such pyroxenes were presumed to be diopsidic. No pigeonites were observed.

Chemical Compositions.

Analyses of the Older Volcanic rocks are not as numerous as could be desired. The chemical compositions of the dyke rocks in South Gippsland and Bendigo have been given elsewhere (10, 48). In the two tables that follow (Tables I. and II.), all the existing analyses of Older Volcanic basalts other than these are set out. They are too few for well-defined groups to show out, but suggest that the differences between the Moorooduc, Flinders, Mirboo, and Keilor types are petrographical rather than chemical. This probably applies to the Berwick type also.

Table I.

—	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	47·70	45·29	51·31	46 64	47·89	46·04	45·64	46·43	44·91	44·95
Al_2O_3	17·76	19·83	18·03	15·46	16·16	15·08	14·35	17·60	13·77	15·50
Fe_2O_3	2·23	4·90	1·50	4·49	2·00	5·08	2·08	8·51	5·28	2·04
FeO	8·25	6·43	7·32	7·25	8·88	6·95	10·32	2·44	5·81	10·47
MgO	6·50	2·49	5·60	7·24	6·23	7·02	9·50	8·03	12·19	7·43
CaO	9·37	9·80	8·74	10·80	10·39	7·75	7·87	8·12	8·56	8·24
Na_2O	3·34	4·24	3·30	2·43	3·37	3·76	2·17	3·56	1·73	3·04
K_2O	1·59	1·96	2·26	0·92	1·47	2·41	1·23	0·92	0·94	1·98
H_2O + ...	0·85	1·02	0·79	1·83	1·34	1·20	1·92	1·20	3·40	2·60
H_2O −	0·27	0·38	..	0·89	0·15	0·57	1·29	0·81	1·34	0·52
CO_2	tr.	nil	0·88	tr.	nil	nil	0·47	nil	tr.	0·18
TiO_2	1·02	2·35	tr.	1·90	1·75	2·78	2·74	2·25	1·73	2·77
P_2O_5	0·51	0·62	0·45	0·32	0 78	1 44	0 42	0·37	0·32	0·52
MnO	0·24	0·23	tr.	0·04	0·19	0·28	0·13	0·22	0·33	0·21
Li_2O	..	..	..	..	..	..	..	..	tr.	..
Cl	0·03	tr.	..	..	tr.	tr.	0·02	..	nil	..
S	0·02	nil	..	..	tr.	tr.	0·14	..	nil	..
BaO	0·03	..	..	..	..	..	nil	..	..	..
Total ..	99·69	99·45	100·18	100·21	100·60	100·36	100·40	100·53	100·39	100·45

(1) Corrected for Cl, S

(7) Cr_2O_3 ·01
V_2O_5 ·05
SrO ·02
ZrO_2 ·03
NiO ·07

(9) NiO·03
CoO tr.
Cr_2O_3·05

1. Crinanite dyke (not rich in analcite), creek west of Gibson's allotment, Kilcunda. Analyst—A. B. Edwards (*Proc. Roy. Soc. Vic.*, 47, 1, p. 123, 1934).
2. Mugearite pipe, Binn's Creek, Aberfeldy. Analyst—W. L. Robertson (Mem. Geol. Surv. Vic., 15, p. 45, 1925). (See note p. 85.)
3. Tachylyte, Tanjil. Analyst—A. W. Howitt (Vic. Nat., 2, p. 67, 1885).
4. Moorooduc type, porphyritic variety, Korkuperrimul Creek Analyst—R. Jacobson (*Proc. Roy. Soc. Vic.*, 50, 1, 1937).
5. Flinders type, Mt. Lookout, Aberfeldy. Analyst—M. K. Evans (Mem. Geol. Surv. Vic. 15, p. 45, 1925).
6. Flinders type, Mt. Lookout, Aberfeldy. Analyst—M. K. Evans (Mem. Geol. Surv. Vic., 15, p. 45, 1925).
7. Flinders type, railway cutting, Royal Park, Melbourne. Analyst—W. McCance (*Proc. Roy. Soc. Vic.* 44, 2, 1932).
8. Flinders type, fine-grained flow, Greensborough. Analyst—N. R. Junner (*Proc. Roy. Soc. Vic.*, 25, 2, p. 335, 1913).
9. Mirboo type, Berry's Creek Bore, No. 20, depth 90 feet, allot. 34, Mardan. Analyst —A. G. Hall (Ann. Rept. Sec. Mines, 1911, p. 62).
10. Keilor type, Quarry, section xv., Tullamarine (Broadmeadows). Analyst—F. L. Stillwell (*Proc. Roy. Soc. Vic.*, 24, 2, 1912).

TABLE II.

—	1.	2.	3.	4.	5.	6.
SiO_2	41·13	42·39	39·79	44·67	44·56	45·56
Al_2O_3	15·74	16·17	12·11	12·39	11·68	13·32
Fe_2O_3	4·02	4·29	4·67	3·96	3·95	2·30
FeO	7·71	5·79	7·87	7·53	6·88	9·68
MgO	7·98	7·66	12·25	9·67	11·91	11·12
CaO	10·48	11·57	11·29	10·16	10·37	8·77
Na2O	5·56	4·26	2·83	1·84	1·03	3·02
K_2O	1·12	1·46	1·23	1·85	2·31	1·53
H_2O + ...	2·11	1·85	1·79	3·92	2·97	1·28
H_2O −	0·58	0·56	3·06	0·92	0·84	0·27
CO_2	nil	nil	nil	tr.	nil	nil
TiO_2	2·34	2·13	1·87	2·52	2·90	3·00
P_2O_5	0·54	1·16	1·30	0·14	0·40	0·71
MnO	0·14	0·23	0·02	tr.	0·24	0·19
Li_2O	tr.	..	..	..	tr.	nil
SO_3	nil	..	..	0·15	..	nil
S	..	0·13	..	0·47	0·06	..
Cl	nil	0·11	..	tr.	tr.	0·05
BaO	..	0·01	..	..	..	..
NiO, CoO	..	nil	..	..	0·01	0·01
Cr_2O_3	..	0·03	..	..	0·09	0·06
V_2O_3	..	0·01	..	..	..	..
TOTAL ..	99·45	99·70	100·08	100·19	100·20	100·87

1. Olivine-nephelinite, Allotment 91, Parish of Drouin West, plug. Analyst—F. F. Field (*Proc. Roy. Soc. Vic.*, xliii., 2, p. 128, 1930).
2. Olivine-nephelinite, plug 8 chains S. of Greendale Hotel, Parish of Blackwood. Analyst—A. B. Edwards (*Proc. Roy. Soc. Vic.*, xlvii., 1, p. 123, 1934).
3. Olivine-nephelinite, lava flow (limburgitic phase), 50 yards from the head of a small gully on the western slopes of Bald Hill, Bacchus Marsh. Analyst—R. Jacobson (*Proc. Roy. Soc. Vic.*, 50, 1, p. 145, 1937).
4. Limburgite, dyke, Blackwall Mine, Aberfeldy. Analyst—M. K. Evans (Mem. Geol. Surv. Victoria, No. 15, p. 44).
5. Limburgite, small flow, Euroa. Analyst—A. G. Hall (Ann. Rept. Sec. for Mines, for year 1912, p. 62).
6. Limburgite plug at Balwyn. Analyst—P. W. G. Bayley (*Proc. Roy. Soc. Vic.*, xxiv., n.s. 1, p. 133, 1911).

If analyses 1, 2, and 3 of Table I., and all of Table II. are excepted as differentiated types, then the average of the remainder (Table I., Nos. 4-10) which are the widespread, little differentiated types, gives a composition which may be regarded as approximating to the composition of the "parent magma" of the suite. This shown in Table III. below:—

TABLE III.

—	Older Volcanic Magma type.	Newer Volcanic Magma type.	Olivine-basalt Magma type.	Tholeiite Magma type.
SiO_2	46	50	45	50
Al_2O_3	15·5	15	15	13
FeO, Fe_2O_3	11·5	11·5	13	13
MgO	8	8·5	8	5
CaO	8·8	8·5	9	10
Na_2O	2·9	3·0	2·5	2·8
K_2O	1·4	1·2	0·5	1·2

From this it seems probable that the parent magma of the Older Volcanic Series approximates to the "olivine-basalt magma type" (26), and is also fairly comparable with the parent magma of the Newer Volcanic Series. This, however, as indicated by its SiO_2 content, is more nearly intermediate between the olivine-basalt magma type and the tholeiite magma type. The Older Volcanics show little resemblance to the tholeiites.

Comparison with Other Tertiary Lavas in Victoria.

It remains to compare the Older Volcanic Series with the other Tertiary igneous rocks of Victoria.

Newer Volcanic Series.

There is a general similarity between the Newer and the Older Volcanic Series in that both are olivine-basalt associations, and gave rise to alkaline end-products. There are, however, some outstanding differences:—

1. Existing analyses indicate that the basalts of the Older Volcanic Series approach more closely to the olivine-basalt magma type in composition than those of the Newer Volcanic Series, which have tholeiitic tendencies.

2. The dominant basalts of the Newer Volcanic Series (Malmsbury and Footscray types) are characterised by an abundance of iddingsite and a paucity of titanaugite (12). On the other hand, titanaugite is the common pyroxene of many Older Volcanic basalts, while iddingsite is of only local occurrence.

3. Crinanites are unknown among the Newer Volcanics, but are widespread among the Older Volcanics.

4. Such Newer Volcanic basalts as do not contain iddingsite are generally associated with more completely differentiated types, such as mugearites, trachyandesites, and trachytes.

5. Mugearites are prominently developed among the Newer Volcanics, but are rare among the Older Volcanic rocks. This finds further expression in the fact that the differentiated Newer Volcanic types are rich both in soda and potash, while the comparable rocks among the Older Volcanics are rich in soda.

6. Basic alkaline types are only weakly developed among the Newer Volcanics, where some limburgites contain analcite. Among the Older Volcanics, however, olivine-nephelinites are of relatively frequent occurrence.

7. Dykes are uncommon among the Newer Volcanics, but are prevalent among the Older Volcanic rocks.

8. The Newer Volcanic basalts are relatively fine-grained, and generally have intergranular textures. The Malmsbury and Footscray types are greyish in colour when fresh, and often vesicular, while the Trentham type and mugearites are bluish-green when fresh. The titanaugite members of the Older Volcanic basalts, on the other hand, generally possess ophitic textures, and are frequently relatively coarse-grained. Older Volcanic basalts are rarely vesicular, and are generally dark coloured, so that they possess a distinctive appearance even in the hand specimen.

There can be little doubt, therefore, as to the difference between these two suites of Tertiary lavas. It cannot, of course, be claimed that the petrological examination of any specimen is sufficient to assign it to one or other suite, but for a number of rock types this is so, and fortunately these types occur in a number of areas.

Suggested Intermediate Series.

Jutson (23) has suggested that on physiographic grounds the basalts at Ivanhoe and Greensborough, and possibly those at Kangaroo Grounds, are of Pliocene age, and intermediate between the Older and Newer Volcanics. The Greensborough and Kangaroo Ground basalts have been described by Junner (21). The basalts at both localities include ophitic olivine-titanaugite dolerites, identical with those of the Older Volcanic Series, and an identical type occurs as a small residual at Diamond Creek in the same district. In view of the uncertain nature of Jutson's evidence, it seems probable to the author that these residuals are Older Volcanic and not Pliocene.

Other Gippsland Localities.

The lavas in the Gelantipy area, and those in the neighbourhood of Benambra, shown as Newer Volcanic on the 8 miles to an inch map of Victoria of 1902, and as Older Volcanic on the 16 inch maps of 1909 and 1936, appear on petrological evidence to be Newer Volcanic. Iddingsite basalts of the Malmsbury-Footscray group are found at both localities, together with less distinctive types. This agrees with the physiographic evidence (18).

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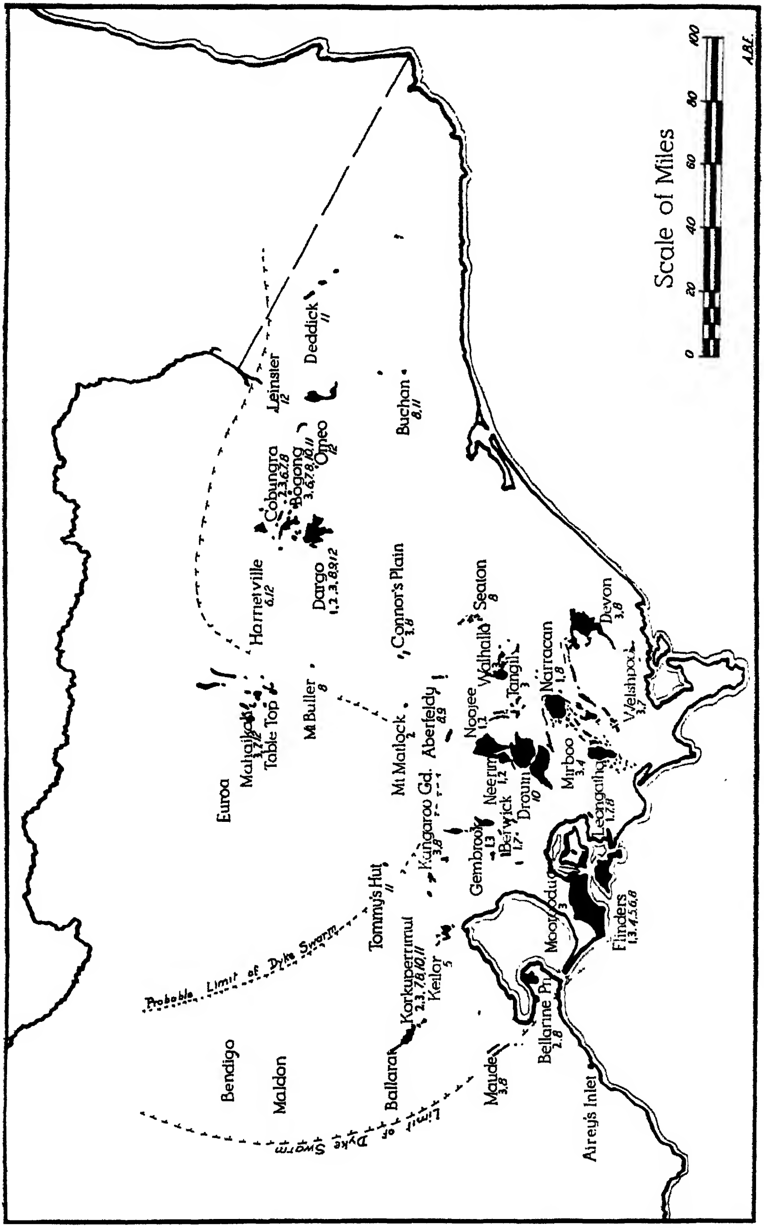

Scale of Miles
0 20 40 60 80 100
A.B.E.
Probable Limit of Dyke Swarm
Limit of Dyke Swarm
Euroa
Mansfield
Table Top
Harrietville
Dargo
Cobungra
Bogong
Omeo
Leinster
Deddick
Buchan
Connor's Plain
Mt Buller
Mt Matlock
Aberfeldy
Kangaroo Gd.
Tommy's Hut
Korkuperrimul
Keilor
Bendigo
Maldon
Ballarat
Maude
Bellarine Pn.
Airey's Inlet
Mornington
Flinders
Gembrook
Berwick
Neerim
Drouin
Noojee
Walhalla
Seaton
Tanjil
Narracan
Mirboo
Leongatha
Welshpool
Devon

FIG. 1.

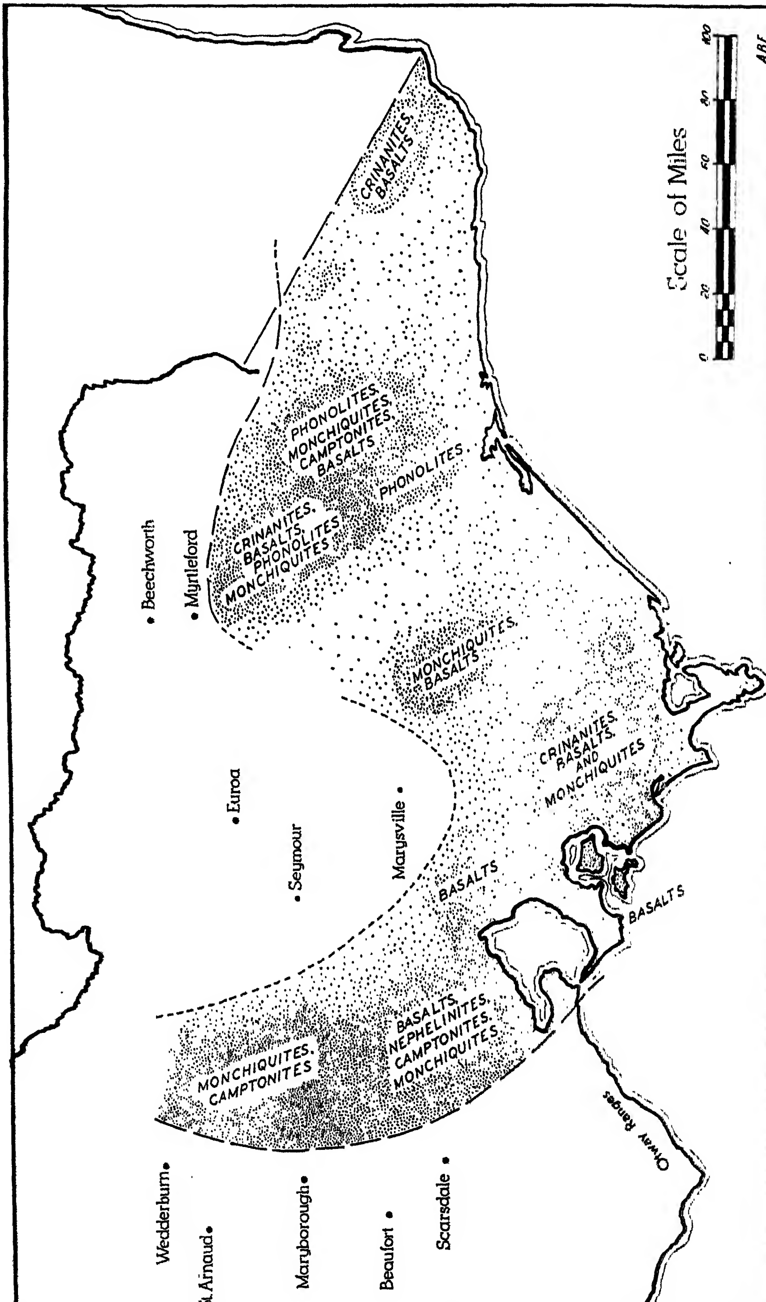

CRINANITES. BASALTS
PHONOLITES. MONCHIQUITES. CAMPTONITES. BASALTS
PHONOLITES
CRINANITES. BASALTS. PHONOLITES MONCHIQUITES
MONCHIQUITES. BASALTS
CRINANITES. BASALTS. AND MONCHIQUITES
BASALTS
BASALTS
BASALTS. NEPHELINITES. CAMPTONITES. MONCHIQUITES.
MONCHIQUITES. CAMPTONITES
Beechworth
Myrtleford
Euroa
Seymour
Marysville
Wedderburn
St. Arnaud
Maryborough
Beaufort
Scarsdale
Otway Ranges
Scale of Miles
0
20
40
60
80
100
ABL.

FIG. 2.

[PROC. ROY. SOC. VICTORIA, 51 (N.S.), PT. I., 1938.]

ART. VI.—*Two Gregarines from Ctenolepisma Longicaudata with Notes on Forms in other Silverfish.*

By EDER LINDSAY, B.Agr.Sc.

[Read 14th July, 1938; issued separately, 23rd January, 1939.]

During the study of the feeding habits of the silverfish *Ctenolepisma longicaudata* Esch. it was found that these insects were frequently infected with gregarines. This silverfish has not been studied previously, but gregarines have been found in related genera. Watson-Kamm recorded one gregarine from *Lepisma saccharina*, *Gregarina lagenoides* Labbé, but did not mention the two gregarines which J. W. Cornwall, 1915, had found in the same species. More recently J. A. Adams, 1935, described two new forms from *Thermobia domestica*, namely *Lepismatophila thermobiae*, and *Colepismatophila watsonae*, for which he created the two new genera.

Two new gregarines were found in the mid-intestines of *Ctenolepisma longicaudata*, and these have been named *Lepismatophila ctenolepismae*, sp. nov. and *Gregarina ctenolepismae*, sp. nov. The former is a large form which was easily seen during the dissections, but the latter was noticed only when the insects were examined under the binocular ($\times 70$).

Most of the insects were collected in Melbourne, but the wide distribution of the parasites was evident from the infested insects collected in Toowoomba and Brisbane, Queensland; Bigga, N.S.W.; Renmark, S.A.; Launceston, Tasmania; and Boyup Brook, W.A.

Materials and Methods.

As the trophozoites live in the mid-intestine, the alimentary canals posterior to the crop were dissected out, slit longitudinally, and the contents examined in water. Fixed preparations were also made following the methods of MacKinnon and Ray 1933. The alimentary canals were immersed in Carnoy's fluid for twelve hours. Some were then stained twenty minutes in Ehrlich's haematoxylin and finally dissected in clove oil. Others were cut into sections 5-7μ thick, longitudinally and transversely, and stained three minutes in Ehrlich's haematoxylin. This stain differentiated clearly the different parts of the protoplasm of the gregarines. The trophozoites were more difficult to fix than the tissues of the gut, and in several sections the larger ones tended to break.

The cyst wall was impervious to stains and no attempt was made to follow the nuclear changes associated with the development of the cyst, but at various stages during the ripening the contents of the cysts were examined after fixing with Carnoy, breaking the wall, and staining with haematoxylin or saffranin.

In the dissected insects the trophozoites of both forms were found attached to the epithelium of the crypts in the sacculi and anterior part of the mid-intestine. Here they caused the atrophy of the neighbouring cells, but apparently no other damage, even where the infestation was so heavy that the parasites occupied the greater part of the gut. The infestations of both forms were usually heavy, frequently 20 or 30 individuals of both gregarines occurring in a single insect. Generally these were of various sizes, and observations extending over two years showed that the gregarines had no seasonal cycle so that the silverfish were always liable to be infested.

Lepismatophila ctenolepismae sp. nov.

This form was found in about 80 per cent. of the silverfish examined.

Trophozoite.—The earliest stages of the life cycle are presumably passed inside the epithelial cells, but the smallest trophozoites found were already extracellular. In one case a minute form was located, shown in Fig. 3, which may be a young trophozite. The body of the smallest form which could be recognized with certainty was cylindrical though not divided, and had a large spherical epimerite embedded between the epithelial cells. Observations at later stages showed that the septum between the protomerite and deutomerite then develops, and the front end becomes broader and broader, until the whole trophozoite becomes roughly "turnip-shaped" (Figs. 4 and 5). Later the more mature trophozoite rounds off with the protomerite remaining as a capping at one end. It was of interest to notice that the "tail" region gradually merged into the body of the trophozoite without leaving the sucker-like scar referred to by MacKinnon and Ray, 1931, in *Selenidium.*

The protoplasms of the three divisions of the young trophozoite appear different in transmitted light and stain differently with Ehrlich's haematoxylin. That of the deutomerite is the most densely granular particularly around the nucleus. That of the protomerite, though less dense, shows a coarse structure when fixed and stains more deeply than the deutomerite. This same coarse structure appears, however, in the deutomerites of many of the more mature trophozoites (Fig. 2, *l.c.*), and frequently tiny granules which stained deeply with haematoxylin were found imbedded in the protoplasm. The protoplasm of the epimerite is densely granular and when fixed shows a fine structure.

The nucleus is 25–40μ in diameter in about the centre of the wide part of the deutomerite. By exerting gentle pressure it can be moved about the body. When stained it shows one caryosome.

The body is bounded by the pellicle which is thin in the region of the epimerite and protomerite but forms a thick refractive coat to the deutomerite and, in the tail region, is thrown into three or four transverse ridges. In the transverse section the "tail" shows as a lightly granular disc surrounded by more deeply stained material enclosed by the thick pellicle (Fig. 2*a*). The mature trophozoites break free of the intestinal walls, usually with the epimerites still attached. These latter become less granular as the gregarines move down the intestine, and finally disappear from the trophozoites. Detached epimerites were never found.

Some of the free trophozoites still remain pressed close to the walls below the sacculi, fitting into small depressions where the epithelial cells have atrophied (Fig. 2). The mature trophozoites pass down the mid-intestine in groups of 20 or 30 lying between the intestinal wall and the peritrophic membrane (Fig. 19, Plate VI.). No temporary associations are made in the group, but when the trophozoites reach the posterior end of the mid-intestine association occurs, protomerite to protomerite, usually between only one or two pairs at a time. These sporonts secrete a white cyst wall, and pass into the hind intestine. Unassociated sporonts did not pass into the hind intestine as had been noticed by Cornwall.

Cyst.—The shining white cysts are conspicuous in the faecal material, usually one being attached to each pellet. They are of two distinct forms, round and oval. As both these forms gave rise to the same kind of spores they were considered to belong to the same species of gregarine. Of 25 cysts measured, the average size of the spherical cysts was $252\mu \times 238\mu$ and of the larger oval cysts $316\mu \times 466\mu$ (standard deviation of 14μ).

The cysts were freed of faecal matter and kept under both moist and dry conditions at 23°C. so that the development could be followed. The cysts from fresh faeces usually contain two sporonts although development sometimes proceeded further inside the intestine. Development proceeds under dry conditions or in water. The cyst wall darkens, becoming first a mottled grey, then black as the cyst ripens. The sporonts divide into many gametes, each about 13μ diameter, but no sexual differentiation could be seen. Then hundreds of tiny spores, almost transparent, separate around the granular residual protoplasm which forms into many non-nucleated masses, which become more definite, though they still can be readily plasmolysed. These and the large oil globules in the cyst gradually disappear as the spores ripen. The spores have a large central nucleus and thick transparent walls which gradually become thicker and darker. At the same time the cyst wall becomes darker, and

the pitted and grooved dark outer layer can be separated from the colourless inner layer (Fig. 8). The cyst finally ripens in about fourteen days.

The ripe cyst is black and dented, and through the semi-transparent wall the dark spores can be seen crowded towards one end. The ripe spores are black, semi-transparent, flattened ovals with one side more curved than the other, 15 to 17μ long, 4 to 6μ wide, and 4μ thick. Each has a large globule at its centre with smaller globules at the end and along the more curved side (Fig. 9). The spores tend to hold together end to end (Fig. 10) and when liberated by the rupture of the cyst come out in many long spring-like chains, extending in some cases for about 8 mms. around the cyst.

The spores contaminate the food and so reach the insects' intestine again. Many spores were found in the crops examined. Some were broken across the middle and some at one end; but no spores split longitudinally as described by Cornwall. Broken spores were also found in the hind intestine but no spores were noticed in the act of germination. The spores could not be broken by pressure and stains would not penetrate the thick capsule so that the sporozoites could not be distinguished. But the heavy infestations would suggest that each spore contains several sporozoites. (Cornwall found 8 sporozoites.)

TABLE 1.—MEASUREMENTS OF TROPHOZOITES OF LEPISMATOPHILA CTENOLEPISMAE (MICRONS).

Total Length.	Protomerite.		Deutomerite.		Epimerite Width.
	Length.	Width.	Length.	Width.	
429	352	168	76	153	..
400	..	..	..	184	..
386	306	177	79	165	..
341	262	81	..	..	37
283	..	171	..	153	..

GREGARINA CTENOLEPISMAE sp. nov.

This smaller gregarine was found in about half the silverfish dissected.

Trophozoite.—The trophoziote is heart shaped, about as long as wide, and attached to the wall by a peg-like epimerite set in the depression at the top of the "heart." The body is not divided into protomerite and deutomerite. The nucleus (6–9μ diameter) is at the base of the depression, and seems to be attached to the pellicle (cf. Chakravarty, 1935). In the living gregarine it is hidden by the densely granular protoplasm. When fixed, the protoplasm shows a finer structure than in the previous form. Around the nucleus it stains deeply with haematoxylin, and deeply stained strands radiate from the nuclear area. The pellicle is thin.

The smallest form recognized measured $5\mu \times 7.3\mu$ (Fig. 13), but most of the gregarines were larger than this (Table 2). The gregarines occur singly or in pairs, the outer one, the satellite, fitting over the primite still attached to the wall (Figs. 11 and 12). There seems to be no other record of syzygy occurring while the gregarines are still attached to the walls (Wenyon 1926, p. 1146, and Henry 1932). Usually both members are the same size, or the satellite is a little larger. During dissection the larger pairs readily come free of the wall with the epimerite still attached. They frequently separate from each other and roll over so that the epimerite is hidden in the depression at the top.

Usually only a few free pairs of trophozoites and associating sporonts are found in the lower part of the mid-intestine, instead of the large group of unassociated trophozoites found in the *L. ctenolepismae* infestation. It is not certain that the same pair remained associated until mature, for by the time the sporonts had encysted they were no longer fitting over each other but were in the position indicated in Fig. 14.

Cyst.—The small shining white cysts containing the two sporonts pass out with the faeces, usually three or four adhering to each pellet. At first the wall is thin (3μ), but thickens to about 6μ and finally to 10μ as the sporonts fuse and the cyst ripens. It stains deeply with haematoxylin. In three days eight to nine spore ducts protrude through the cyst wall from the protoplasmic mass inside. These grow out about 10μ from the cyst (Figs. 15 and 16). In six days at 23°C. the tiny white

TABLE 2.—MEASUREMENTS OF GREGARINA CTENOLEPISMAE (MICRONS).

Unassociated Trophozoites.

Width.	Length.
18·0	18·0
34·0	31·6
73·4	65·5
78·6	78·6
78·6	76·0
92·0	82·0
94·3	91·8
99·8	94·3
145·0	141·0
161·0	122·0

Trophozoites in Syzygy.		Young Cysts.	
Width.	Total Length of Pair.	Width.	Length.
microns	microns	microns	microns
84	145	69	69
107	153	107	95
153	184	84	69
230	260	100	107
..	..	84	84

refractive spores exude in chains from the ducts like fine white filaments extending about 1.4 mm. around the cyst (Fig. 17). The regular oval spores measure $3.2\mu \times 2.2\mu$. The small amount of residual protoplasm consists mainly of globules about half the size of the spores.

The cyst matures in the dry faeces. If kept in water the young cysts plasmolyse, and the older cysts swell till about 125μ diameter.

Feeding Experiments.

An attempt was made to follow the development of the gregarines in the intestine of the silverfish. The insects were supplied with clean food until cysts were no longer found in the fresh faeces. They were then fed for two days with food artificially infected with ripe spores of both gregarines, and then removed to clean food which was changed daily. Subsequent dissections and sections revealed trophozoites of various ages in the mid-intestine and many spores in the crop, but no germinating spores or very small trophozoites. The insects were held at 23°C. throughout.

To find the duration of the trophozoite stage a group of naturally infested insects were fed on clean food and the faeces examined daily for cysts. Dissection of several insects, during these observations revealed the presence of trophozoites in the mid-intestine. After 26 days, however, no more trophozoites of *Gregarina ctenolepismae* were present and cysts were no longer found in the faeces. Further, on the 35th day no cysts of *Lepismatophila ctenolepismae* were found, and dissection of the remaining thirteen insects showed that only one harboured mature trophozoites. Since sporonts and cysts were never found to collect in the hind part of the intestine it is concluded that these periods give a lower limit to the duration of the trophozoite stage.

To facilitate the examination of the mid-intestine the infected food was stained with Sudan III. which is taken up by the epithelial cells. The trophozoites of *Gregarina ctenolepismae* take up a little of the red and appear pink surrounded by the red epithelial cells. The trophozoites of *Lepismatophila ctenolepismae* remain uncoloured.

Systematic Position.

In general characteristics the two gregarines described resemble somewhat those found by Cornwall and Adams, but detailed examination showed several differences. For example, *Lepismatophila ctenolepismae*, sp. nov. resembles *Lepismatophila thermobiae* but the spores have not the regular oval shape described by Adams, one side being more convex than the other.

It also resembles Cornwall's form A, but the spore walls are smooth instead of pitted. *Gregarina ctenolepismae,* sp. nov. resembles Cornwall's form B, but the epimerite is peg-like rather than acicular as figured by Cornwall.

Following the classification of Watson-Kamm (1922) both gregarines are placed in the family Gregarinidae; the larger form as a new species of Adams' genus *Lepismatophila, Lepismatophila ctenolepismae,* and the small form as a new species of *Gregarina* (Dufour), *Gregarina ctenolepismae.*

Diagnosis.

Lepismatophila ctenolepismae sp. nov.

No syzygy in sporonts. Trophozoite septate, conoid, 390μ $\times$ 164μ. Epimerite smooth, globular. Cyst round 245μ diameter; or oval, 315μ $\times$ 460, dehisce by rupture. Cyst wall black, pitted and grooved. Spores in uncoiling chains. Spores black, ellipsoidal, one side more convex than the other, 16μ $\times$ 5μ $\times$ 4μ. Spore wall smooth.

Gregarina ctenolepismae sp. nov.

Syzygy in cephalonts and sporonts. Trophozoites heart shaped 87μ wide $\times$ 80μ long, non-septate. Epimerite simple peg shape. Cyst white, smooth-walled, spherical 85μ diameter. Spores liberated in chains through spore ducts. Spores oval 3.2μ $\times$ 2.2μ. Spores white smooth walled.

Gregarines in other Silverfish.

The intestines of other species of silverfish were examined for gregarines. *Lepisma saccharina,* the common pest of the Northern Hemisphere is found only occasionally in Australia. Of the six so far examined, three harboured a trophozoite, (Fig. 18) different from the gregarines so far recorded for the *Lepismatidae. Ctenolepisma lineata* var *pilifera* is another form collected occasionally with the common silverfish. Three individuals were examined, and in one were found several trophozoites resembling *Lepismatophila ctenolepismae* Luc. These insects had been kept for a time in captivity and several cysts were found in the faeces which had collected. These were small and round and contained the typical spores of this same gregarine. Somewhat similar trophozoites were found in two preserved specimens of *Thermobia aegyptica* Luc. A few native silverfish have been examined, one *Acrotelsella,* and one *Heterolepisma,* collected with the common silverfish, two from termites nests, and two from under bark, but none have contained gregarines.

It is interesting to note that the three species collected together in houses have not the same parasites though they have the same feeding habits and presumably would have the same chances of infection. *Lepismatophila ctenolepismae* occurs only in *Ctenolepisma longicaudata*, and *Ctenolipisma lineata* var *pilifera* which have sacculi in the mid-intestine and not in *Lepisma saccharina* where these are absent. Sufficient material of *Thermobia aegyptica* was not available to permit any conclusion regarding the identity of the gregarines found, and further examination is necessary before any importance can be attached to the absence of gregarines in the native forms.

Summary.

Two new gregarines have been found in the silverfish *Ctenolepisma longicaudata* Esch—which have been named *Lepismatophila ctenolepismae* and *Gregarina ctenolepismae.* These have been described and their life cycle followed. Further, to determine the specificity of the gregarines, several other species of silverfish have been examined. *Lepismatophila ctenolepismae* sp. nov. was found only in *Ctenolepisma lineata* var. *pilifera* Luc. A different form was found in *Lepisma saccharina* (Fig 18) and two unidentified forms in *Thermobia aegyptica* Luc.

Acknowledgment.

The author wishes to thank Miss J. Raff for her guidance and Professor S. M. Wadham for many suggestions; also Mr. Ogilvie for the microphotographs and Dr. Turner for advice regarding the naming of the species.

Explanation of Figures.

Fig. 1.—Longitudinal section of the anterior portion of the mid-intestine showing trophozoite stage of the two gregarines, l.c. *Lepismatophila ctenolepismae,* and g.c. *Gregarina ctenolepismae,* in the epithelial lining of the sacculi. Portions *a* and *b* show the sacculi not cut in true section, *f* folds in epithelium below the sacculi, *crp.* crypts, *v.* villi. × 38.

Fig. 2.—Tangential longitudinal section of the lower mid-intestine, showing a group of mature trophozoites. *l.c. L. ctenolepismae*, *a* section of "tail" region, *d.pr.* sporonts with dense protoplasm, *g.c. G. ctenolepismae.* × 38.

LEPISMATOPHILA CTENOLEPISMAE.—Figs. 3-10.

Fig. 3.—A form found in the sections which may be a young trophozoite 9 μ × 2 μ. × 250.

Fig. 4.—Young trophozoite showing epimerite, drawn from two successive sections. × 250.

Fig. 5.—Outlines of both free and attached forms of trophozoites drawn from living material to show the variation in shape. × 100.

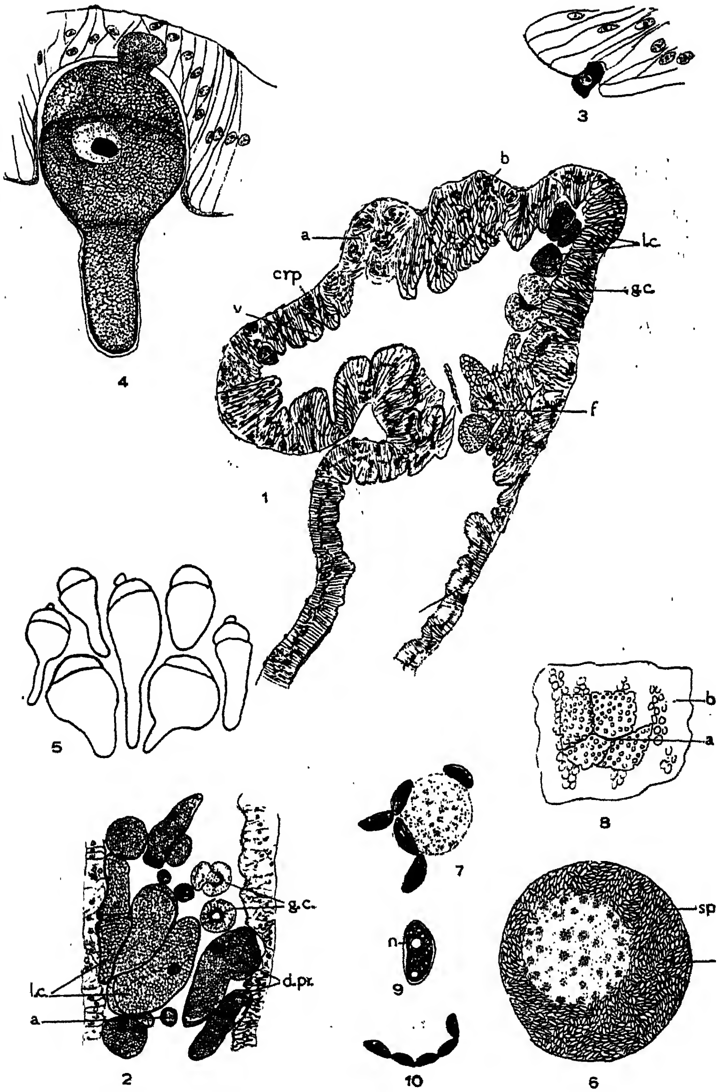
Fig. 6.—Optical section of developing cyst. The transparent spores have separated around the central mass of protoplasm. × 60.

Fig. 7.—Young spores and spherical mass of protoplasm from a fractured cyst. × 300.

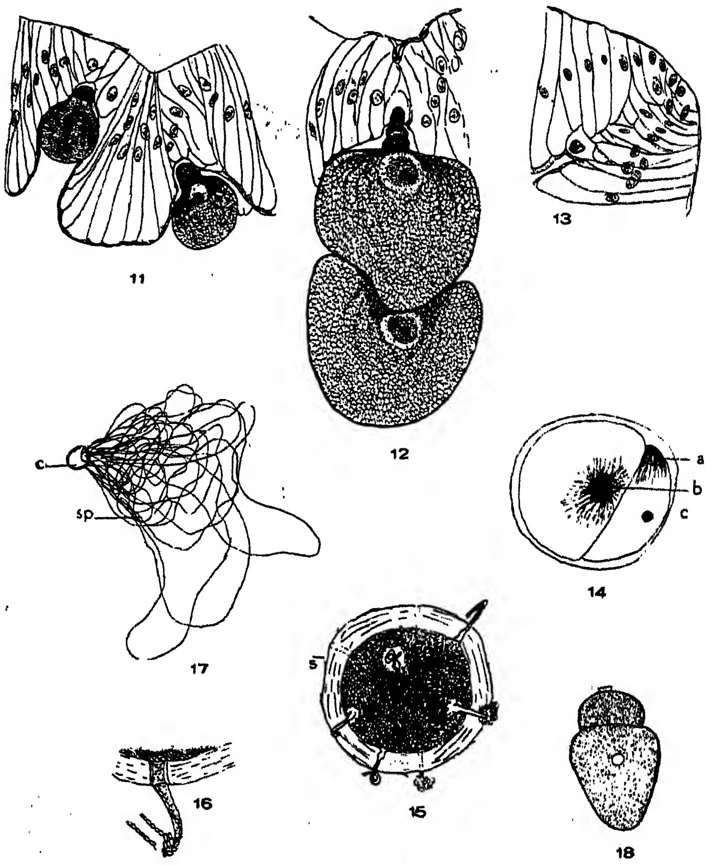
Fig. 8.—Cyst wall with pits and grooves.
a. Groove in outer black layer of wall.
b. Inner colourless layer marked by circular areas. × 340.

Fig. 9.—Optical section of ripe spore, showing the nucleus *n* and other globules. × 310.

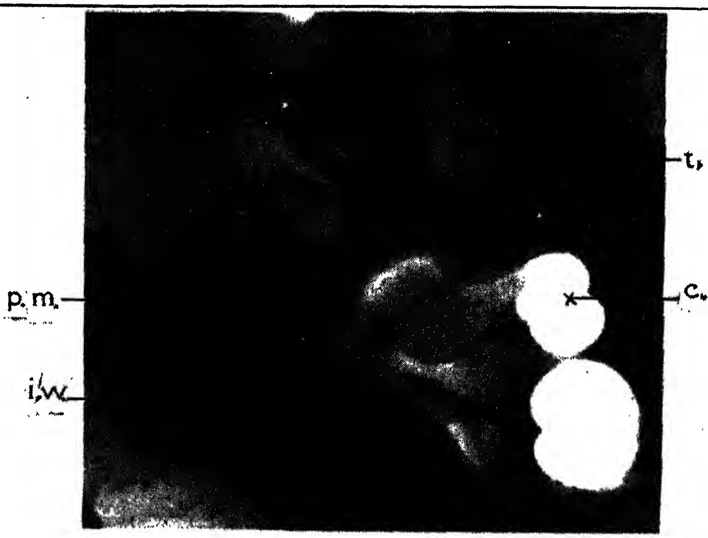
Fig. 10.—Chain of ripe spores. × 330.



Text Figs. 1–10.



Text Figs. 11–20.



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GREGARINA CTENOLEPISMAE—Figs. 11-17.

Fig. 11.—Trophozoites. × 250.

Fig. 12.—Large trophozoites in syzygy drawn from 3 sections. × 250.

Fig. 13.—A small gregarine intracellular $4.9\mu \times 7.3\mu$ (× 250).

Fig. 14.—Optical section of a newly formed cyst enclosing the associated sporonts. Stained with Ehrlich's haematoxylin.

a. Heavily stained area of second sporont. × 340.

b. Heavily stained protoplasm surrounding the nucleus.

c. Nucleus of second sporont.

Fig. 15.—Cyst showing spore ducts. × 340.

Fig. 16.—Spore duct of cyst with chain of spores exuding through duct. × 400.

Fig. 17.—Ripe cyst *c.* with chains of spores *sp.* exuded. × 15.

Fig. 18.—Unidentified trophozoite from *Lepisma saccharina.* × 180.

PLATE VI.

Fig. 19.—Microphotograph lower part of mid-intestine opened to show trophozoites *t.* and cysts *c.* of *Lepismatophila ctenolepismae* lying between the intestinal wall *i.w.* and the food enclosed in the peritrophic membrane *p.m.* × 480.

Fig. 20.—Microphotograph of large trophozoites of *Gregarina ctenolepismae* in syzygy, attached to the epithelium *e.p.* by the epimerite *e.* × 230.

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ART. VII.—*The Age and Physiographic Relationships of the Cainozoic Volcanic Rocks of Victoria.*

By EDWIN SHERBON HILLS, Ph.D.

[Read 14th July, 1938; issued separately, 23rd January, 1939.]

I. Introduction.

It has always been realized that the determination of the geological ages of the various Cainozoic lavas that occur in this State is a difficult task, and that, as Skeats has remarked, one's conclusions must frequently be based "only on conjecture or analogy." Nevertheless, by correlating stratigraphical, petrological and physiographical data collected over a long period, certain generalisations have been arrived at concerning these rocks, which have been widely, though not universally, accepted. Thus it has come to be believed that there were two main periods of eruptive activity during the Cainozoic Era, during which an Older Volcanic Series, of Oligocene to Lower Miocene age, and a Newer Volcanic Series, of Pliocene to Recent age, were developed (Smyth, 1858; Skeats, 1910; Singleton, 1935). Furthermore, maps published after 1902, on which the Older and Newer Volcanics are differentiated, show all the Cainozoic lavas east of the meridian of Melbourne as Older Volcanics, Newer Volcanics being restricted to the region west of the meridian of Melbourne. This view was tentatively accepted by Skeats (1910) in the absence of definite evidence that would indicate the presence of Newer Volcanics in eastern Victoria, and I also adopted it in discussing the physiography of the Eastern Highlands (1935). Recent work, however, indicates that this generalisation is unsound, and evidence for the presence of Newer Volcanic rocks in the Eastern Highlands will be presented in the first section of this paper.

The Newer Volcanic Series is currently regarded as dominantly Pleistocene with a few Pliocene and Recent members (Singleton, 1935, p. 134; Jutson and Coulson 1937), but Walcott (1920, p. 83) has suggested that the upper flows at Pitfield Plains, which are typical Newer Volcanics as far as their field occurrence is concerned, may be Miocene in age, and that there may have been no well marked break in volcanic activity between the extrusion of the Older and Newer Volcanic Series. Sussmilch (1937) has gone further, and grouped most of the Newer and Older Volcanics, so distinguished by Victorian geologists, together as Lower Pliocene, and David (1932, Table I.) regarded the main period of extrusion of the Newer Series as Upper Pliocene. In

early official publications by members of the Geological Survey (summarised in Murray's *Victoria: Geology and Physiography*, 1895) the Newer Volcanic Series was also stated to be Pliocene, but in a recent pamphlet (Prospector's Guide, 3rd Edn., 1936) these rocks are classed as Pliocene to Recent.

In view of the conflict of opinion regarding the age relationships of the Older and Newer Volcanics, I propose to discuss in the second section of this paper the evidence adduced by previous authors concerning the age of these rocks, together with such new stratigraphical and physiographical evidence as I have been able to obtain. Edwards (1938) has recently discussed the petrology of the Older Volcanic lavas, and data from this aspect will be dealt with only incidentally in the following account.

II. The Cainozoic Lavas of Eastern Victoria.

In view of the wide acceptance of the generalisation concerning the non-existence of Newer Volcanics in this district, which is given official recognition in the latest geological map of the State published by the Mines Department (1936), and also in an earlier edition (1908), it is interesting to note that on the larger scale, 1902 map (1 inch=8 miles), several patches of Newer Volcanic rocks are marked in the Eastern Highlands. In the legend of this map, however, one such patch (Gelantipy) is classed as Older Volcanic, suggesting that this and the other patches may have been coloured as Newer Volcanic owing to an oversight. On the other hand, Dunn, who was Director of the Survey when the map was prepared, has referred in print (1914) to one such patch, a few miles south of Euroa, mentioning the occurrence of scoria cones, ash beds, and vesicular and dense lavas which he compared with the typical Newer Volcanics of Western Victoria. It may be, therefore, that the colouring was given to these occurrences intentionally, but, if so, no reason for the subsequent change in the 1908 map, on which they are shown as Older Volcanics, is known to me, and there are indications in the older literature that the view expressed on the 1902 map may have had some foundation in the beliefs of the geologists of the last century.

It is clear, for instance, that it was at first only McCoy's comparison (1878) of the sub-basaltic leaf remains on the Dargo and Bogong High Plains with the Miocene flora of Europe that caused the Survey to class these and other Cainozoic lavas in the Eastern and South Gippsland Highlands as Older Volcanics, for Howitt (1879) stated that he believed all the North Gippsland occurrences, including those of the High Plains, Morass Creek, Gelantipy, and South Buchan, to be Newer Volcanics. Owing to McCoy's work and the partial elucidation of the stratigraphy of South Gippsland, the High Plains occurrences and those of Aberfeldy, the South Gippsland Highlands, Berwick, &c., were

subsequently classed as Older Volcanics, but since no published statement as to the existence of stratigraphical or physiographical evidence of the age of many of the smaller patches of lava in the Eastern Highlands had been made, I conclude that later reference to these as Older Volcanics (e.g. Dunn (1907) and Murray (1908) on Morass Creek, and the Geological Survey in the 1908 and 1936 maps) are based "only on conjecture or analogy."

Direct stratigraphical evidence that would serve to define precisely the ages of these patches is, indeed, lacking, and one is necessarily forced to rely on physiographical analogies with occurrences whose age can be determined from stratigraphical data. South Central Victoria and South Gippsland afford excellent standards by which to judge the age of the lavas of the Eastern Highlands, for their geology and physiography are known in considerable detail, and they afford examples of lavas of diverse age and physiographical setting. They will therefore be used as key areas in the following discussion.

Older Volcanics in South Central Victoria and South Gippsland.

Although Sussmilch has argued that the so-called Older Volcanic lavas of Berwick, Tanjil, Aberfeldy, Narracan, and Morwell are of Lower Pliocene age, all Victorian workers are agreed that they are either Oligocene or Lower Miocene. The latter belief is founded in part upon the direct stratigraphical evidence that the lavas are interbedded with the base of the main lignite series, which is regarded (Singleton, 1935, p. 128) as either of the same age or slightly older than Lower Miocene or Upper Oligocene marine beds penetrated in bores further to the east. This evidence appears to be reasonably sound if the lignites penetrated in the eastern bores may be correlated approximately with those of the Morwell district, and Sussmilch's claim that the Morwell lignites may pass upwards into the Lower Pliocene has little bearing on the age of the basalts, since these occur near the base of the series (Edwards, 1938).

By avoiding any attempt at correlation of the definitely Pre-Miocene Older Volcanics of the Mornington Peninsula and Melbourne District with those of Berwick and South Gippsland, Sussmilch minimizes the evidence that the former afford as to the age of the latter. This procedure is not justified, however, for the lavas of the Mornington Peninsula are separated from those of South Gippsland only by the Koo-wee-rup swamp, which is an area depressed by late Tertiary faulting, during which, as shown by boring, the basalts were thrown down to 436 feet below sea level at Lang Lang. There is no reason to doubt that before the faulting a more or less continuous lava field stretched from Drouin and Heath Hill to the Peninsula (Keble, 1918), with outlying residuals as at Berwick and Mt. Ararat, east of Berwick.

As in South Gippsland, leaf beds are associated with the lavas on the Mornington Peninsula and also in the Melbourne district. The continuity of physiographical conditions is obvious, and there can be little doubt as to the similarity of age. This is shown to be Lower or pre-Miocene by the evidence of bores at Tooradin and surface geology near Melbourne, so it may be concluded that, of the lavas specifically referred to as Lower Pliocene by Sussmilch, the Tanjil, Tanjil East, Narracan, Berwick, Morwell, and Aberfeldy occurrences are in reality Lower Miocene or Oligocene, and would therefore be referred to the Older Volcanic Series, as is generally recognized in Victoria.

Physiographically these lavas are characterized by their mature dissection, and the fact that they have been affected by block faulting of probable Middle or Upper Pliocene date (Hills, 1935). South of the Eastern Highland boundary the lavas have been elevated to 1.500 feet above sea level in the South Gippsland Highlands, and depressed 300 feet below sea level, beneath the Gippsland Plain at Yarragon. Where they have been exposed at the surface in these districts, all initial superficial features of the flows have been completely obliterated, and such centres of eruption as have been recognized have been completely degraded, no longer retaining the form of hills of accumulation (Edwards, 1934).

North of the Gippsland Plains, on the southern slopes of the Eastern Highlands, block faulting is no longer important, and residuals such as the Tanjil series and those on the interfluve between the Aberfeldy and Thomson Rivers slope gradually downwards towards the plains where they pass beneath Tertiary sediments. These residuals are maturely dissected, and again no initial superficial features are preserved. Their physiographic setting is shown in the block diagram (Fig. 1). In all essentials the authenticated Older Volcanics of the Melbourne district show physiographic features comparable with those above described for the Gippsland lavas.

THE CAINOZOIC LAVAS OF THE EASTERN HIGHLANDS.

Morass Creek.—The lavas of the Morass Creek extend from Uplands, about 6 miles north of Benambra township, to the Gibbo River, a distance of about 10 miles. They have been mapped by Stirling (1888), who classed them simply as Tertiary, but on the 1902 geological map they are shown as Newer Volcanic, while on later maps they are shown as Older. Skeats (1910) followed the later maps, referring them to the Older Volcanic Series, and Murray (1908) did the same. In recent publications, however, Thomas (1937, pp. 572-575) and Kenny (1937, pp. 461-464) have briefly indicated the physiographic youth of the lavas, and Easton (1937,

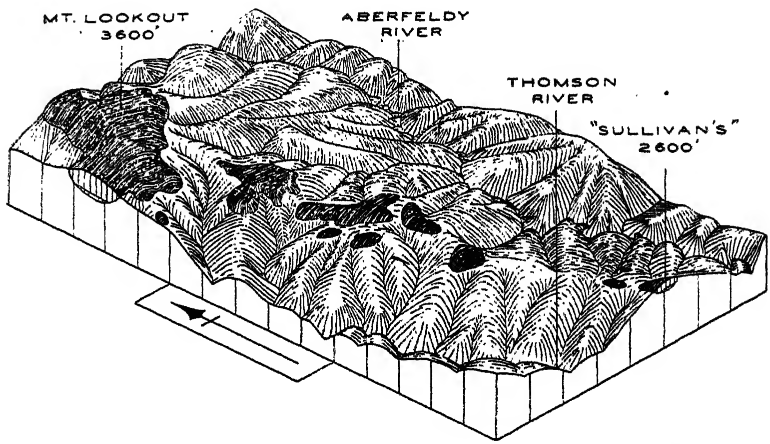

Fig. 1.—Block Diagram to illustrate the physiographic setting of the Older Volcanic lava residuals betwen the Thomson and Aberfeldy Rivers. Approximate scale North-South, 1 in. = 1½ miles.

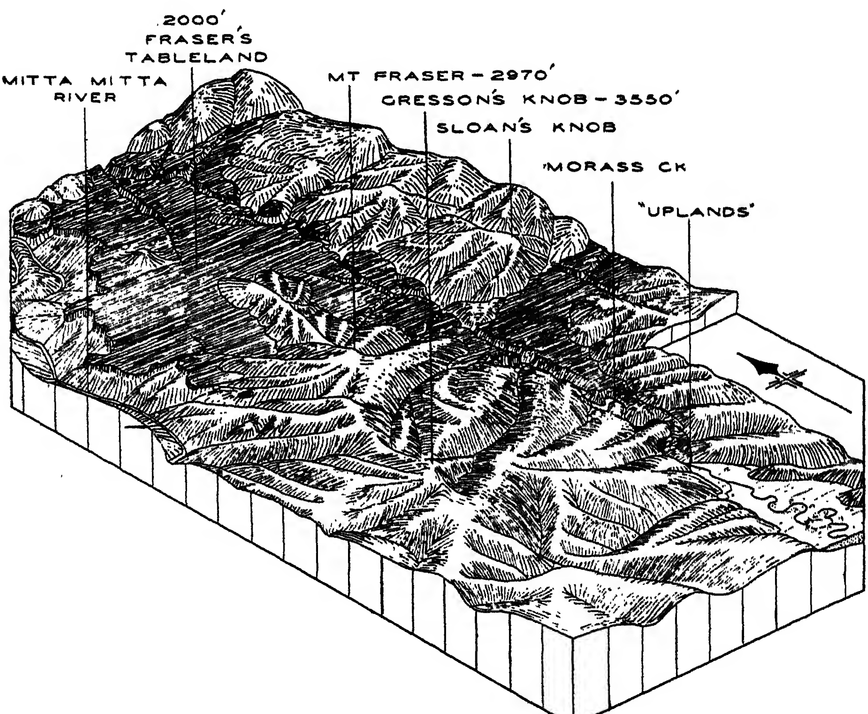

Fig. 2.—Block Diagram to illustrate the physiographic setting of the Morass Creek basalts. Approximate scale North-South, 1 in. = 1½ miles.

p. 507) actually refers to them as Newer Basalts. I visited the district in 1937, and the following account is based mainly on personal observation.

The valley of Morass Creek has been excavated in hard Palaeozoic rocks, mainly slates, conglomerates, gneisses, and porphyries. In the neighbourhood of Benambra the valley floor is broad and marshy with a shallow lake adjacent to the town, on the eastern side of the low ridge separating the basin of Lake Omeo from Morass Creek. The alluviated portion of the valley narrows to the north (downstream) and at Uplands the Morass Creek basalts are to be seen. From this point downstream to the Gibbo River, the main valley floor is occupied by lavas, several superposed flows being recognisable in cliff sections. All the specimens examined petrologically are basalts, and it will be convenient to refer to the suite as the Morass Creek basalts.

As is shown in the block diagram (Fig. 2), the walls of the pre-basaltic valley rise high above the lavas, which flowed both up and down the valley of the pre-existing stream, probably from a centre of eruption marked by the hill rising above Fraser's Tableland. They also flowed up the valleys of tributary streams, and, as Easton has shown, up the valley of the Gibbo River for a distance of about 5 miles, where they dammed the river and initiated a lake in which extensive deposits of alluvium were laid down (1937, p. 508). The flat-topped lava plateaus such as Fraser's Tableland, with their surfaces dotted with boulders of vesicular basalt, are reminiscent of many of the young lava plains of Western Victoria, and, as in this district, the stage of dissection of the flows is youthful. The Morass Creek has now cut a gorge, mainly along the eastern edge of the basalts, but over extensive areas the initial surfaces of the upper flows are but little modified by erosion.

A feature strongly indicative of youth is the preservation of the broad alluvial flats upstream from Uplands. Topographic data supplied by the maps of the State Electricity Commission show that the whole of the alluviated reach lies below the level of the top of the basalts and is indeed almost a horizontal plane surface. There can be no doubt that these flats were deposited in a lake formed by the damming of Morass Creek by the basalts. Although this lake has been drained owing to the lowering of the basalt barrier as the creek has become incised into it, large areas are still marshy, and near Benambra a small lake still remains. It is only in the actual vicinity of the barrier that the flats are now beginning to be removed by the stream.

It will be clear that the Morass Creek basalts are in no way comparable physiographically with the typical Older Volcanics of the key areas. The Aberfeldy residuals, which lie at approximately the same elevation above sea level as the Morass Creek flows, afford a standard for comparison (see Figs. 1 and 2), and

the vastly greater denudation that these Older Volcanics have suffered under comparable physical conditions indicates the relative youthfulness of the Morass Creek flows. In the preservation of the lacustrine deposits, the slight degree of modification of the initial surface features of the flows by erosion, the existence of a hill of accumulation at the probable point of eruption, and the youthful nature of the Morass Creek where it traverses the lavas, they resemble the Newer Volcanic basalts that occupy the valley of the lower Yarra, which will later be shown to be probably Pleistocene in age.

In view of the fact that they are situated at an elevation of more than 2,000 feet above sea level, it may be assumed that the Morass Creek basalts are perhaps even younger than those of the Yarra valley. In any case, the conclusion is unavoidable that they are late Cainozoic, and thus referable to the Newer Volcanic Series. A short account of the petrology of the basalts will be found in the Appendix.

Gelantipy.—The Cainozoic lavas of this district lie on the tableland between the Murrendal River on the west and the Snowy River on the east, about 2,000 feet above the latter stream (Ferguson, 1899). They extend for about 20 miles as a north-south strip, commencing from a point about 10 miles north of Buchan. According to the reports of Ferguson, and Brough Smyth's account of Murray's explorations (1875, p. 5), the basalt ends in escarpments along the Snowy River, but hills of porphyry and Devonian limestone rise above the flows. Ferguson mentions the occurrence in shaly layers of the wash beneath the lavas, of leaf impressions "resembling Miocene forms" (1899, p. 21). Howitt (1879) at first regarded the lavas as Newer Volcanics, and they were marked as such on the 1902 map, but Dunn (1907) referred to them as Older Volcanics, and they have been marked as such on later maps. Petrologically all the specimens examined may be broadly described as basalts (see Appendix), and the suite will be referred to herein as the Gelantipy basalts.

The physiographic features shown by these lavas, where I examined them near Gelantipy, are certainly not as youthful as those of the Morass Creek basalts. In the Gelantipy district they do, however, still lie below the level of the walls of the pre-basaltic valleys, and it is clear from the above descriptions that they are also lower than remnants of the pre-basaltic interfluves in other places. The Snowy River is well known to be a particularly powerful stream, and Ferguson's account shows that it is physiographically youthful in the area under consideration. In places the walls of its gorge are only 30 feet apart. Thus, it is quite conceivable that its 2,000 feet deep valley should have been excavated along the edge of the basalt flows during a relatively short period. At Gelantipy the dissection of the flows is much less advanced than that of the Older Volcanic residuals at Aberfeldy

and Tanjil, being comparable with that of many of the Newer Volcanic lavas on and near the divide in Central Victoria. I consider, therefore, that the Gelantipy basalts are younger than the Older Volcanics of South Gippsland. They are, however, older than the Morass Creek basalts, since the initial surface features of the flows have been much modified by erosion, and I would suggest that they are probably comparable in age with the Pliocene members of the Newer Volcanic Series, which will be described later.

South Buchan.—The small patch of basalt (see Appendix) occurring at this locality lies at an elevation of less than 1,000 feet above sea level. The surface features are largely obscured by soil, and it is possible that the existing occurrences are only remnants of larger flows.

On some of the hills both north and south of Buchan, high-level fluviatile gravels and sands occur that one would class, in the absence of definite evidence, as probably Pliocene, by analogy with the alluvial leads in Western Victoria. The Pliocene Torrent Gravels of the Gippsland Plain, too, extend up for some miles into the southern part of the Eastern Highlands as hill cappings up to 600 feet above sea level (Howitt, 1875), and it is not unreasonable to suppose that the Buchan gravels are of similar age to these. On a hill a few miles south of Buchan a thoroughly decomposed basic dyke, well exposed in a road cutting, cuts the gravels, and what appear to be lenticular basic flows, now also decomposed, are interbedded with them. In the absence of more definite evidence concerning the age of the gravels, it would be hazardous to assume a Pliocene age for the dyke and interbedded flows, or to relate them to the South Buchan basalts. The impression gained in the field is, however, that the latter may be even younger than the hill cappings of gravel, as they occur at lower levels than these, and also lie below the neighbouring hills of Devonian limestone. Although very indefinite, the indications are that the South Buchan basalts may perhaps be regarded as Upper Cainozoic or at least younger than the Oligocene and Miocene Older Volcanics of South Gippsland. Howitt (1879) mentioned them as Newer Volcanics, Murray (1875) as Older, and they were shown as Newer on the 1902 map, but Older on the 1908 and later ones.

Euroa.—In the valley of the Seven Creeks, from about three miles south of Euroa for a distance of seven miles upstream, there is an isolated patch of Cainozoic limburgites (see Appendix) which like those occurrences above discussed, was marked as Newer Volcanic on the 1902 map, and Older Volcanic on later maps. Dunn (1914) has given a very brief account of these lavas, referring to the presence of scoria and ash beds and small volcanic cones. From personal observation, I would confirm Dunn's remarks as to the recent appearance of the flows in this

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district, though in a rapid examination of the district I was unable to discover any scoriae or ashes. This small lava field occupies the floor of the main valley of the Seven Creeks, which is deeply incised into the surrounding granitic tableland of the Strathbogie Ranges. Both dense and vesicular varieties of the limburgites occur, and many of the small flows have the peculiar ridge-like form of the Western District stony rises. Two rocky prominences near the confluence of the Wombat and Seven Creeks are probably among those referred to as points of eruption by Dunn, but their real nature is not absolutely certain. They break suddenly up from the surrounding well grassed plains, and ridges suggesting flows emanate from them.

If they merely represent residual hills owing their rocky character to some initial difference in texture of the flows, it is difficult to explain the almost complete absence of limburgite boulders in the creeks, which are filled with sand from the neighbouring granites. In any case, the position of the lavas in the floor of the main valley, and the lack of co-ordination of the drainage in the lava-filled section of this valley, are clear evidence of the youth of the flows, and they are to be correlated with the younger members of the Newer Volcanic Series.

Although I have not investigated in detail any of the other patches of Cainozoic lavas in the Eastern Highlands, it may be pertinent to summarize such information as is available concerning them.

At Glenmaggie basalts whose relationships to the Tertiaries of the Gippsland plain are uncertain but which still lie below the level of the interfluves of the pre-volcanic streams, have been described by Murray (1877), who compared them with the Older Volcanics of Tanjil (p. 56). Mr. Baragwanath informs me, however, that he considers the Glenmaggie basalts to be younger than the typical Older Volcanics of South Gippsland, since they do not occur as residuals capping the hills, but lie in the pre-basaltic valleys, whose walls in places rise above them.

Owing to their association with the *Cinnamomum* flora, the Dargo and Bogong basalts must be regarded as not younger than the Lower Pliocene, and possibly as of greater antiquity than this, since this flora was already well developed in Oligocene times (see p. 124). Hunter (1898) considered that there is evidence of two flows in places, with an erosion interval between them. Mr. M. A. Condon has recently surveyed portions of these High Plains, and has kindly supplied me with a sketch section showing the mode of occurrence of a small patch of scoriae, agglomerate, and tuffs with associated lavas, at Roper's Lookout, near Mt. Cope. He considers the section to be portion of a denuded volcanic cone, and if this is substantiated by later work, it would constitute the first record of its kind in the High Plains. Occurring as it does as an isolated patch some

distance from the main lava residuals, the occurrence has no direct bearing on the age of the latter. It does indicate, however, the possibility that late Cainozoic volcanic activity may have taken place in the district, for it is unlikely that a superficial and easily erodable deposit such as these pyroclastic rocks afford, would have been preserved under the conditions of strong denudation that obtain in the High Plains, since early or middle Cainozoic times.

Finally at Mahaikah, petrologically typical Older Volcanics overlie lignities of possibly Oligocene or Lower Miocene age (Edwards, 1938).

It will now be clear, firstly that definitely Newer Volcanic rocks occur in the Eastern Highlands, at Morass Creek and Euroa, and possibly also at Roper's Lookout, near Mt. Cope. Authentic Older Volcanic flows also occur at Mahiakah, in the Aberfeldy, Tanjil, Berwick, and other districts, and also in the South Gippsland Highlands, and in the Gippsland Plains. The Dargo and Bogong High Plains may have flows of several different ages, but the main suite is perhaps to be classed with the Older Volcanic Series. The Gelantipy and South Buchan basalts and also those of Glenmaggie are of doubtful age, but the available evidence indicates that they are intermediate between the Morass Creek basalts and the Older Volcanics of South Gippsland, and may provisionally be regarded as Newer Volcanics.

III. The Cainozoic Volcanic Rocks of Western Victoria.

In recent publications Singleton (1935), Sussmilch (1937), and Jutson and Coulson (1937) have discussed in general terms the question of the age of the so-called Newer Volcanic Series in the area west of the meridian of Melbourne. There is general agreement that some of these rocks are of Recent age, but while Singleton and also Jutson and Coulson place the main period of extrusive activity in the Pleistocene, Sussmilch regards is as Lower Pliocene. Coulson (1938) has defined with some precision the ages of several individual flows in the Geelong district, the ages assigned ranging from Upper Pliocene to Pleistocene.

The stratigraphic data used to determine the ages of the volcanic rocks by these authors differ to some extent. Sussmilch relies mainly upon the evidence of the deep lead floras such as those of Pitfield Plains and the Haddon lead, but makes use also of Keble's interpretation of the geology of the Drik Drik district, and physiographical evidence. Jutson and Coulson base their conclusions upon the relationship of the basalts to the old consolidated Pleistocene dunes, the Lara and Limeburner's Point limestones, the shell beds described by them at Portarlington, and on their interpretation of the history of the Port Phillip area

during late Cainozoic times. Largely as a result of their interpretation of the Portarlington beds, they reach conclusions as to the coastal geology of the Port Phillip area which diverge widely from those formerly accepted, and would necessitate, if accepted, very considerable modification of our ideas as to the physiographic evolution of this area. References to most of the older literature are to be found in the above works, also in Walcott's paper (1920) on the age of the auriferous drifts, and in Hunter's account of the deep leads (1909).

The Evidence of the Fossil Floras.

As a result of his survey of the deep lead floras, Sussmilch draws the conclusion that the fruits and leaves occurring beneath or interbedded with the lavas of Dargo, Narracan, Berwick, Morwell, Bacchus Marsh, and Pitfield, in Victoria, Vegetable Creek and Dalton in New South Wales, and the Redbank Plains in south-eastern Queensland, belong essentially to a single floral association called by him the *Cinnamomum* Flora. Although he recognizes that some of the members of this flora existed in pre-Pliocene times, perhaps even in the Miocene, he concludes that the flora was "abundant and widespread in Pliocene times", and would regard most of the lavas associated with the flora as Lower Pliocene. This position seems to me to be untenable, for if the evidence from the bores in East Gippsland, above referred to, may be taken as demonstrating the Oligocene or Miocene age of the Yallournian lignites, then the *Cinnamomum* Flora must have been already well established in these periods. In view of Sussmilch's claim that the flora is more characteristic of the Pliocene than of older periods, the further evidence of its antiquity afforded by the Redbank Plains beds, in Queensland, is significant. There, *Cinnamomum* and other members of the flora are associated with fresh water fish remains, which I have referred, with some reservation, to the Oligocene (1934). Sussmilch, however, discounts the evidence of age afforded by the fishes, noting that *Epiceratodus denticulatus,* from the Redbank Plains beds, is close to the Pleistocene and Recent *E. forsteri*; that *Phareodus queenslandicus* is a new species and thus perhaps of little stratigraphical value; that *Notogoneus parvus* is of doubtful generic position, and that *Percalates antiquus* closely resembles the living *P. colonorum.* I have, however, gone further into the evidence of age afforded by these fishes, and have no reason to doubt their Lower Tertiary age.

It may be pointed out that all other known species of the genus *Phareodus,* as well as the related genus *Musperia* (Sanders, 1934), which occurs in Sumatra, are restricted to the Eocene. Furthermore, the distinction between *P. queenslandicus* and the Eocene *P. testis,* from North America, so far as I have been able

to judge from published descriptions and from photographs kindly supplied by the Museum of Comparative Zoology, Harvard, and the American Museum of Natural History, New York, is based only on differences of a minor nature. They reside chiefly in the number of vertebrae, which may vary within the limits of a single species, and the dentition, which is largely developed in response to feeding habits: I have not been able to compare the squamation. In referring the Queensland species to the Oligocene I have made some concession to the evidence of a younger age for these beds, which is afforded by the presence in them of *Epiceratodus* and *Percalates* (see below).

Concerning the doubtful generic position of the Gonorhynchid, *Notogoneus,* upon which Mr. Sussmilch comments, I consider that the essential point for our present purposes is not the generic position of the fish, but the fact that we have to deal with a member of a well-defined group within the family. This group, which includes *Notogoneus* (with which the Queensland example is undoubtedly closely allied), *Colpopholis* and *Phalacropholis* of Europe and North America, is confined to fresh water deposits, whereas the living members of the family are marine. These fresh water Gonorhynchids range from Ypresian (Eocene) to Rupelian (Oligocene) (see Chabanaud, 1931), and there are therefore strong grounds for referring the Redbank Plains beds to one or other of these Lower Tertiary periods.

Although *Percalates antiquus* resembles the living *P. colonorum* very closely, I cannot agree that this indicates a younger age than I have suggested. The osteological characters of Percoid fishes are remarkably stable, even generic distinctions being based, when osteological characters are used as a criterion, on such minor features as the nature of the spines on the pre-operculum (see Woodward, 1901, p. 504). Thus, the Eocene *Cyclopoma* is distinguished from the living *Lates* solely on differences in these spines, and as the differences between *P. colonorum* and *P. antiquus* are of a higher order than this, though in my opinion not such as to warrant generic separation, I think it is reasonable to assume that the fossil species is not, of necessity, to be regarded as Upper Tertiary. Little can be said concerning the Dipnoan, *Epiceratodus denticulatus,* in view of the fragmentary nature of the remains, but it may be remarked that *Epiceratodus* ranges down into the Cretaceous (White, 1926), and as the Redbank Plains fish is distinct from *E. forsteri,* its occurrence in presumably Oligocene beds is not inconsistant with the known facts.

In view of these considerations, I think it is justifiable to rely mainly on the Osteoglossid and Gonorhynchid as index fossils, since these give definite evidence of age, in so far as our present knowledge goes. These forms indicate an Eocene

or Oligocene age, and in suggesting the latter I have made some concession to the claims of the other species. In my opinion it is preferable to regard the evidence from the Redbank Plains as indicating the antiquity of the *Cinnamomum* flora, rather than the youth of the fish remains.

The *Cinnamomum* flora is essentially an Australian one (Deane, 1901), and includes not only genera (e.g. *Cinnamomum*) that are restricted to-day to the warmer and moister parts of the continent, but also genera such as *Casuarina* and *Eucalyptus* that still live in Victoria. It is clear, therefore, that climate or topographic changes have caused the dying out of the sub-tropical types in Victoria, while other genera have lived on in spite of such changes.

I have already shown (1935) that during the Pliocene, important earth movements took place in Victoria, and it may be that the existing floral association was initiated during and after these movements, which may have been accompanied by a climatic change. *Cinnamomum* itself is known to occur in beds at Beaumaris that may be either Lower Pliocene or Upper Miocene in age (Singleton, 1935), but there is no evidence of its occurrence in Victoria in beds shown by the evidence of marine fossils to be younger than the Lower Pliocene.

Due allowance being made for the incompleteness of the fossil record, it may be assumed, therefore, (1) that *Cinnamomum*, and other genera belonging to Deane's "brush" type of flora, not now living in Victoria but found in the warmer and moister parts of Australia, serve to indicate an Oligocene, Miocene, or possibly Lower Pliocene age; and (2) that an "open forest" flora from which the above types are absent, but which includes *Eucalyptus*, *Banksia*, *Casuarina*, and other genera now living in the State, indicates a post-Lower Pliocene age. The possibility must also be considered that communities of the older flora may have persisted locally under favourable conditions into post-Lower Pliocene times, especially along the southern portions of the Eastern Australian Cordillera, in New South Wales.

In view of these conclusions, the association of the *Cinnamomum* flora with volcanic rocks at Glenfine, south of Pitfield, assumes considerable importance. Sussmilch (1937, p. xvi) accepts this association at its face value as indicating that all the basalts at Pitfield, including the upper flows which are typical members of the Western District suite, are Lower Pliocene in age. Walcott (1920, p. 86) considers that the basalts may be even older than this, being Middle or Lower Tertiary, since they "must have had [their] origin in the same period" as the leaf beds and the gold drift.

Chapman and Singleton (1923, p. 14) have indicated, however, that the lower basalts at Glenfine are probably Older Volcanics, and this view has much to support it. The section at Glenfine

is shown in Figure 3. There is only a patch of about 40 acres where the lower lavas occur (Hunter, 1901), and it will be noted that these occupy a valley eroded in the bedrock. The upper of the two basal flows has, in all probability, been planed down by fluviatile erosion to the level of the rock floor upon which the Pitfield wash rests, and the 40-acre patch of lower basalts must represent only a remnant of formerly more widespread flows. There is thus a considerable time gap between the upper flow and those that underlie it, so that the leaf beds do not prove the superficial lavas of the district to be Lower Pliocene or older.

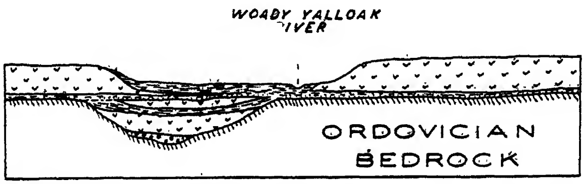

Fig. 3.—Section showing the relationship of the upper and lower lavas at Glenfine Consolidated Mine, Pitfield Plains. The leaf beds with *Cinnamomum* occur between the two lower flows. The auriferous Pitfield wash lies beneath the upper flow. Horizontal scale, 1,600 ft. = 1 in.; vertical scale, 800 ft. = 1 in., datum 140 ft. above S.L. (After Hunter, 1901.)

It remains now to consider the age of the fruit-bearing leads that in places underlie Cainozoic lavas in the Haddon, Nintingbool, Tanjil, Rokewood, and other districts, in relation to that of the *Cinnamomum* Flora, and of the leads with *Eucalyptus, Banksia,* and fossil wood, such as those of Creswick and Eldorado. I believe it to be unlikely that von Mueller's determinations of the affinities of the various fruits he described are to be relied upon, as Deane has shown that certain of his species are allied to living Australian genera, so that there is little point in discussing at length their stratigraphical significance. It is clear that some of the plants from which the fruits were derived existed in Oligocene or Miocene times, since they occur under the undoubted Older Volcanics of Tanjil, but neither their upper nor their lower limit has been precisely defined, and it may be that some of them ranged above the Lower Pliocene, which, as has been shown above, may be regarded as the upper limit of the *Cinnamomum* Flora in Victoria. The Haddon fruit-bearing leads are in all probability younger than the *Cinnamomum* beds of Pitfield (see p. 131).

The Evidence of the Pleistocene Dunes.

At several places around the Victorian coast, from Barwon Heads to Portland, Cainozoic volcanic rocks come into stratigraphic relationship with consolidated calcareous sand dunes

that are generally accepted as Pleistocene in age, though Jutson and Coulson regard them as ranging from Upper Pleistocene to Recent (1937).

The Quaternary stratigraphy of Victoria is not known in sufficient detail to enable the age of the dune rocks to be determined by direct evidence, but if the theory propounded by Sayles (1931) to account for the formation of the remarkably similar ancient dunes of Bermuda be accepted, then it may be possible to arrive at the age of the Victorian dunes by analogy. Having found by detailed studies that there were five periods of active dune-building in Bermuda, separated by periods of soil formation, Sayles correlated the former with periods of maximum ice-cap development during the Pleistocene, and the latter with inter-glacial epochs. It is suggested that, as the waters of the oceans were lowered owing to the growth of ice caps, the broad tracts of sandy sea floor so exposed supplied the material for forming the dunes, and that during inter-glacial and post-glacial times the re-advance of the sea caused active dune building to cease. On this hypothesis, Pleistocene dune-building should have been a world-wide phenomenon, and if it should prove possible to correlate the periods of dune building with those of maximum ice cap development, then the old dunes would form a very convenient geological time scale in non-glaciated regions. Daly (1935) has interpreted the old dune series described by Durègne in Gascony along those lines, and it is interesting to note that Darwin (1876) has compared the consolidated dunes of King George Sound, in Western Australia, with those of the Cape of Good Hope, Madeira, and Bermuda, also noting (p. 99) that the dune limestones of St. Helena must have formed when that island was surrounded by a shelving coast quite unlike its present precipitous shores. Tate (1879) was also impressed with the necessity for postulating a lowering of sea level, which would produce a shelving sandy coastline, to explain the formation of the Pleistocene dunes at the head of the Bight.

The conditions postulated by Sayles and Daly would admirably explain the formation of the old dune series in Victoria. At times of maximum glaciation large tracts of Bass Strait would have been above the sea, and the masses of comminuted shells so exposed would have been blown by southerly and south-westerly winds over the present coastal fringe of Victoria, and the islands in Bass Strait.

On nearly all the islands in the Strait that were examined by Johnston (1888) old consolidated sand dunes occur up to a height of 100 feet above sea level. These old dunes are dominantly composed of fragments of marine shells, but owing to the presence in them of bands rich in various species of land snails such as *Helix*, *Succinea*, etc., Johnston named then the *Helicidae*

Sandstones. Myriads of individuals belonging to various species of these genera live to-day on the vegetation cover of the dunes, and their shells are washed into hollows, forming layers like those found in the dunes themselves. Johnston classed the dunes as Recent in the Table on p. 303 of his book, but listed certain of the fossils obtained from them as Pleistocene (p. 329). David (1932, Table I.) referred them to the base of the Recent period.

Around the south coast of Australia, in Victoria, South Australia, and Western Australia, the old consolidated dunes exhibit similar features to the *Helicidae* Sandstones. At Cape Schanck and Barwon Heads ancient soil layers formed during periods of cessation of dune building are rich in fossilised shells of *Helix* and other land gasteropods, Pritchard (1895) having recorded *Helix* and *Bulimus* from Barwon Heads and also from a point about a mile west of the Gellibrand River. Tate (1879) has referred to similar occurrences of *Helix* and *Bulimus* in the old dunes at the head of the Bight, and Darwin (1876, p. 163) recorded *Helix* from St. George's Sound, where the shells "abound in all the strata." These fossils have no stratigraphical significance since they have not been studied in detail, but they do indicate that the dunes were formed at these different localities under comparable physiographical conditions. All observers are agreed that the consolidated dunes are older than the coastal dunes now forming, and since it is necessary to postulate a different coastal topography from that which now exists, in order to adequately explain their development, it appears to me to be a reasonable assumption that they formed during the world-wide depressions of sea level that occurred during the Pleistocene glaciations.

A noteworthy feature of the old dunes is their division into roughly horizontal layers whose upper and lower surfaces truncate the planes of cross-bedding. This is well shown at Barwon Heads, Cape Schanck, and Cape Otway, and has been described by Wilkinson (1865), Griffiths (1887), and Coulson (1935) in Victoria, and by Tate (1879) in South Australia. These sub-horizontal layers represent periods of cessation of active dune building, during which friable sandy soils, white travertine bands, or black rubbly carbonaceous layers were developed.

At Barwon Heads there is evidence of the presence of five such periods of soil formation after the commencement of the formation of the dunes and before the present day. Without detailed study it would be unsafe to correlate them even tentatively with inter-glacial epochs, as Sayles does with the Bermuda dunes, but consideration of the record of the Sorrento bore (Chapman, 1928) does suggest that the Pleistocene period exhibits in Victoria

a succession of periods of dune building with intervening periods of sand stability, and it may be tentatively assumed, therefore, that the old dunes of the Victorian coast range throughout the Pleistocene. Detailed studies will be necessary to confirm this, but in what follows, formations which are overlain by the consolidated dunes are referred either to pre-Pleistocene or Lower Pleistocene times. This view is opposed to that of Jutson and Coulson, who place the lower portions of the dune series in the Upper Pleistocene, and its upper portions in the Holocene (p. 323). On the view put forward here, the dunes would cease to form when the last ice maximum passed, so that it is only the unconsolidated, and usually very restricted dunes now in process of formation that would be classed as Holocene.

Where the Cainozoic volcanic rocks come into relationship to the Pleistocene dunes, as at Portland, Port Fairy, Warrnambool, and Barwon Heads, we find that the lavas underlie them, but between Port Fairy and Warrnambool, tuffs from Tower Hill overlie them. Clearly, therefore, the Tower Hill tuffs must be classed as late Pleistocene or Recent, and this view has always been the accepted one. The lavas, on the other hand, must be placed either within the Lower Pleistocene, if the dunes do not cover the whole of Pleistocene time, or in pre-Pleistocene times if the base of the dunes is Lower Pleistocene. Since the lavas are nowhere interbedded with the dunes, there are good grounds for assigning to them a pre-Pleistocene or basal Pleistocene age. This conclusion, of course, refers only to the flows at the particular points mentioned.

IV. Regional Summary of Occurrences.

West of the Hopkins River and Bushy Creek.

In the Portland district, basalts, in places deeply weathered and locally associated with tuffs (Kitson, 1906; Dennant, 1887), occupy valleys eroded through Barwonian limestones and through an oyster bed. The latter was referred to as Miocene by Dennant, but was doubtfully correlated with the Ostrea Limestone that conformably overlies the Werrikooian shell beds along the Glenelg River by Singleton (1935). If the Ostrea bed at Portland is Werrikooian, which is not certain, the basalts must be regarded as epi-Pliocene, for they are overlain by Pleistocene dunes at Cape Bridgewater. In places they have a thin capping of sand (Kitson), and have been extensively eroded by the sea along the coast.

Basalts which are probably older than the Portland flows, and form dissected plains and residual ridges, occur at Mt. Clay and the Kangaroo Range, Drik Drik. At the latter locality (see geologically coloured Parish Plan, Drik Drik; also Keble's

remarks in Sussmilch, 1937) the basalts appear to be pre-Werrikooian and are certainly post-Barwonian. These occurrences are outlying patches of a dissected lava plain stretching from the coast northwards to Branxholme, Hamilton, and Dunkeld, and east to the Hopkins River. At Hamilton they overlie marine Kalimnan beds, and they form a physiographically well-defined unit (see Block Diagram, Fig. 4) characterised by deep dissection, especially in the north, and strong weathering. They may therefore be grouped together as post-Lower Pliocene (Kalimnan) and pre-Pleistocene, perhaps pre-Upper Pliocene if their relations to the Werrikooian are correcly interpreted. They may therefore be regarded as Middle Pliocene.

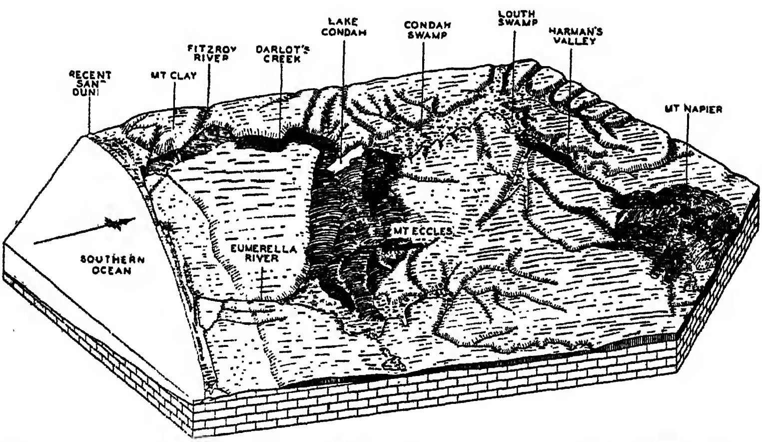

Fig. 4.—Block Diagram to illustrate the physiography of portion of the Western District lava plains. The bedrock, shown diagrammatically, consists of Miocene limestones. These are overlain by maturely dissected Middle Pliocene lavas, except near the coast where the limestones appear at the surface. The Stony Rise flows from Mt. Napier (1,440 ft.) and Mt. Eccles (580 ft.) are shown schematically. Approximate scale North-South, 1 in. = 13 miles.

The Stony Rises.—As shown by Mahony and Grayson (1910, Skeats and James (1937), and by Sussmilch (1937), there are at several localities in the Western District, flows of very recent appearance, which are known as Stony Rises.

In the district under consideration such flows occur around Mt. Napier, Mt. Eccles, and Mt. Rouse. That they are considerably younger than the older lavas referred to above is clear from the fact that, as at Byaduk and the Fitzroy River, they flowed down valleys cut into these lavas. The flow down Harman's Valley, at Byaduk North, appears to be the youngest in the district. At its lower termination, near Wallacedale, it spread out as a wide sheet over the upper reaches of the Condah Swamp, there known as the Louth Swamp, where a remarkable group of

low domes, or "lava blisters," was formed by the expansion of water vapour imprisoned beneath the flow, as shown by Skeats and James. The Condah Swamp itself was caused by the damming back of Darlot's Creek by flows from Mt. Eccles, so that the Harman's Valley flow is younger than these latter. Details of the initial surface features of the flow are still perfectly preserved and there can be no doubt as to its Holocene age. As the other Stony Rises around Mt. Napier have exactly similar relationships to the pre-existing, dissected lava plain as does the Harman's Valley flow, they and the compound scoria cone at the summit of the mount, with its well developed breached crater on the western side, are also to be referred to this period. On the lower flanks of Mt. Napier, on the northern and eastern sides, there are perfectly preserved low scoria cones which are also undoubtedly Holocene.

Mt. Eccles is situated on the northern border of a large and roughly rectangular area of Stony Rises, extending between Darlot's Creek, on the west, and the Eumerella River on the east. A long lava tongue extends southwards from Lake Condah nearly to the coast, separating the Fitzroy River flowing along its western margin from Darlot's Creek along its eastern, until the two streams unite at the termination of the flow. Physiographically these Stony Rises are exactly comparable with those around Mt. Napier, as they occupy, or have over a large area actually obliterated, valleys eroded through the older, presumably Pliocene lavas and the Barwonian limestones that appear along the coast, and they preserve their initial surface features in perfect detail. They dammed back Darlot's Creek, forming the shallow Lake Condah and the Condah Swamp, and are also responsible for the formation of the swamps along the Eumerella River south-west of Macarthur. These features are all indicative of extreme youth, and the flows must be classed as Holocene.

Around Mt. Rouse, Stony Rises of recent appearance exist close to the scoria cone itself, but the flows extending southward for about 10 miles from Penshurst, although physiographically younger than the older flows of the Hamilton and Portland district, are not typical Stony Rises. They appear to be intermediate in age between the Recent flows and the more deeply dissected lavas near Port Fairy that pass beneath the dune limestones, for although they have been weathered much more deeply than the Stony Rises, their topography still reflects in large measure the configuration of individual flows. Nearer the coast stream dissection is important in determining the topography. The Moyne Swamp was not caused by interruption of pre-existing drainage lines by the lavas, as was the Condah Swamp, but occupies a sagged area, perhaps connected with the solution of underlying Tertiary limestones. Since the lavas near the coast

pass beneath the Pleistocene dunes at Port Fairy (Ferguson, 1920), I would suggest that they are to be correlated with the Pliocene flows further west. The Stony Rises near Mt. Rouse are, by analogy with the occurrences at Mt. Napier and Mt. Eccles, to be regarded as Holocene, and the flows south of Penshurst are therefore possibly Pleistocene.

As already indicated, the tuffs from Tower Hill overlie the Pleistocene dunes, forming a layer of variable thickness that follows the topography of the underlying dunes at least as far east as Warrnambool, and west to Port Fairy. Tuffs cover the whole of the Tower Hill Swamp and the marsh north of the Barwonian limestone ridge that runs easterly from Tower Hill, and they also overlie Recent shell beds (Brough Smyth, 1858). The Recent age of the tuffs is thus confirmed.

The District between the Hopkins River and Inverleigh.

The youngest flows in this district are typical Stony Rises, which by analogy with those above described are to be regarded as Holocene. They are developed around Mt. Porndon, the Warrion Hills, and Red Rock (Skeats and James, 1937), and also around Mt. Elephant, Mt. Leura, and Mt. Terang (Mahony and Grayson, 1910). Large areas of the southern portion of this district are covered by tuffs which in places contain or overlie remains of extinct marsupials. At Mamre Station a fossil fern, *Pteris aquilina,* has been obtained from them (Mahony and Grayson, 1910). Although it is often assumed that the giant extinct marsupials are characteristically Pleistocene, Walcott (1920) has shown that they may range from Pliocene to Holocene, so that they cannot be used as index fossils. The tuffs at the Warrion Hills, Red Rock, and Mt. Porndon that overlie the Stony Rises must be Holocene, and those covering the floors of lakes and swamps south-east of Mt. Shadwell and near Camperdown are also probably of this age, as they form a mantle over the countryside like those of Tower Hill, and overlie clays from which an artefact was obtained at the Pejark Marsh (Walcott), 1919).

The older lavas of this district, which are characterised by more extensive weathering, the development of buckshot gravels, and by their dissection by streams have been referred to the Lower Pliocene by Sussmilch, and an even earlier age, perhaps Miocene or older, by Walcott (1920). The evidence adduced by these authors is afforded by the leaf beds at the Glenfine Extended Mine at Pitfield, the Haddon and Nintingbool fruits, and the supposed termination of the Pitfield wash along a Miocene shoreline running westerly from Rokewood. The evidence of the Glenfine leaf beds has already been discussed, and it is clear that they have no bearing on the age of the superficial lavas of the

area. If, however, the sub-basaltic Pitfield wash is really coeval with the Miocene beds further south, then the basalts might conceivably be of an age not far removed from the Miocene. This, however, I would deny, for the evidence from boring shows that the Pitfield wash forms a thin sheet beneath the upper basalts, resting on a planed down bedrock surface that was undoubtedly cut by streams after the uplift of the "Oldest" drifts. These drifts have been compared with the uplifted Kalimnan and Barwonian sands and gravels in the Melbourne district, and may be littoral deposits of Miocene or Lower Pliocene age. The Pitfield wash is younger than these gravels, and Krausé has shown (1886) that the Haddon fruit-bearing leads are also younger than them. Fossil fruits have recently been obtained from the Pitfield Plains, and I regard the Pitfield wash as similar in age to the Haddon and Nintingbool fruit-bearing leads. The basalts, therefore, are Post-Miocene, and may be Pliocene or even younger.

The Geelong and Melbourne Districts.

At the Moorabool Viaduct, flows from the Anakies, which although warped along the Lovely Banks axis, are not deeply dissected (except along their western edge by the Moorabool) overlie calcareous sands, referred by Mulder (1902) to the Werrikooian. Jutson and Coulson (1937) have compared these sands with Pleistocene or Recent shell beds at Portarlington (see below), and Singleton (1935) is doubtful of their Werrikooian age, but the fauna has not been critically reviewed, and their Upper Pliocene age may be accepted for the present. Thus the Anakies flows are either very late Pliocene or younger, and as their dissection by the Moorabool indicates that they are not Recent, they may be either late Pliocene or Pleistocene. Physiographically they resemble the flows from Mt. Duneed that are overlain by Pleistocene dunes at Barwon Heads, and overlie Lower Pliocene sands (Coulson, 1938). I therefore regard them as late Pliocene or early Pleistocene. For further details concerning the Geelong district the paper by Coulson (1938) should be consulted.

In regard to the basalts of the Melbourne district, it is necessary to review the radical changes that Coulson and Jutson have suggested in the interpretations of the Melbourne Tertiaries. They argue from the supposed fact that beds at Portarlington, regarded by them as Pleistocene, grade into ferruginous sands resembling lithologically certain of the Red Beds (Hall, 1911) in the Melbourne district, that these Red Beds are therefore Pleistocene and not Barwonian and Kalimnan, as formerly believed. On this interpretation the basalts of Footscray, Essendon, and the Yarra Valley must be Middle, or, more probably, Upper Pleistocene, as they occupy valleys eroded through the Red Beds.

I have examined the sections described by these authors at the Pier and at Steele's Rock, Portarlington, and can find no evidence of the supposed merging of the calcareous and sandy beds one with the other. At the Pier it appears to me that the shell beds were artificially laid over the ferruginous series, a possibility that was noted and rejected by Jutson and Coulson. The dark, shell-bearing sands merely form a plaster on the old cliff face, and cannot be seen to pass into the sands. At Steele's Rock the shell bed is a true geological stratum, but it is only necessary to indicate the dips of the ferruginous beds on the section given by Jutson and Coulson to see that any merging of the two series is impossible. The ferruginous sands are current bedded and, also, at the eastern end of the section, warped about an axis running southwards, so that their dip is variable, but the shell bed forms a superficial layer overlying the truncated bedding planes of the red sands, on the top of the cliff. These two sections, therefore, do not necessitate any change in the accepted interpretation of the age of the Red Beds of the Geelong and Melbourne districts.

In the Melbourne district the youngest flow is that which occupies the Yarra Valley. Here, young features such as the Gardiner's Creek and Templestowe Flats, which represent alluvium deposited in lakes caused by lava barriers, are still preserved, and in its upper parts the basalt has been but slightly trenched by streams.

As shown by Kitson (1902), the marine deposits recorded beneath the creek alluvium at Forest Hill by Coates (1860) are best explicable on the hypothesis that the basalt cut off an arm of a pre-existing estuary, representing a tributary of the drowned valley of the pre-basaltic Yarra. If the drowning that produced this estuary were correlated with the post-glacial rise of sea level, then the Yarra basalt would be Recent, but its physiographic features indicate a greater antiquity than this, and it may be that the estuary was formed during an inter-glacial epoch, so that the basalt can be assigned to some part of the Pleistocene.

Since the extrusion of the Tertiary basalts of the Keilor Plains, the Maribyrnong River has cut a young valley through them. After this valley was first incised, erosion was temporarily superseded by deposition near the coast, and an alluvial filling was deposited on the valley floor, which was later entrenched, giving the paired terraces of the 40-ft. level at West Essendon and Maribyrnong. Similar paired terraces occur along the lower course of the Moonee Ponds Creek. At a later date still, the mouths of the rivers draining into Hobson's Bay were drowned, causing tidal influences to be felt for a distance of about 9 miles

up the Maribyrnong. It is clear from this sequence of events that these flows dissected by the Maribyrnong are considerably older than those which occupy the valley of the ancestral Yarra, but there is nothing to indicate whether they are Pleistocene or Pliocene. There is no doubt, however, that they are post-Kalimnan.

In regard to the age of the basalts of the Bacchus Marsh district, which overlie sands of doubtfully Upper Miocene age, containing *Cinnamomum*, a little-known paper by Brittlebank (1900) has some significance. By embedding wires of different lengths in the rocks exposed in the bed of the Werribee River, Brittlebank estimated the time that has elapsed since that river began to cut its present gorge. The results from three different stations showed a remarkable agreement, averaging 1,040,000 years. No allowance was made in this estimate for possible higher rainfall during past times or for the effects of undercutting of hard rocks underlain by soft Tertiary sands or glacial deposits, so that the estimate might possibly be more correct if the values given were halved. If this is done, the value of 520,000 years so obtained would place the date of the Rowsley fault somewhere near the beginning of the Pleistocene, so that the basalts are almost certainly Pliocene.

V. Summary and Conclusions.

In this paper the data available for the determination of the ages of the various Cainozoic volcanic rocks of Victoria have been critically reviewed. The *Cinnamomum* Flora has been shown to have a probable range in this State from Oligocene to Lower Pliocene, and the consolidated dune series, which is here correlated with the *Helicidae* Sandstones of the Bass Strait islands, is considered to range throughout the Pleistocene. Use has also been made of physiographical analogies with occurrences of known age, in dealing with the lavas of the Eastern Highlands.

Those volcanic rocks whose ages can be determined with some degree of precision fall into two groups—an Older Series, of Oligocene to Lower Miocene age, and a Newer Series, of Middle Pliocene to Recent age. It is possible that some of the flows that overlie beds containing members of the *Cinnamomum* Flora may bridge the gap between these two series, but no flow that can be dated by marine fossils or other means actually does so. Thus, the suggestion (Walcott, 1920; Edwards, 1938) that volcanic activity may have been continuous from Oligocene to Recent times, with a marked lull in the Middle and Upper Miocene and the Lower Pliocene still remains to be confirmed, and I consider it preferable, as a working hypothesis, to regard the two series as distinct.

Appendix.

Petrological Descriptions.

1. *Morass Creek.*

All the described specimens were obtained from sections along the road from Benambra to Corryong, between Uplands and the Gibbo River. Numbers in brackets refer to slides catalogued in the collection at the Department of Geology, University of Melbourne.

Olivine-iddingsite basalt [5259].—This is a highly vesicular and absolutely fresh rock with a bluish "bloom" in the vesicles. It consists of micro-phenocrysts of partially iddingsitized olivine set in a fine-grained intergranular groundmass of pale greenish-grey augite prisms, laths of basic andesine (Ab_{55}), and iron ore grains. Numerous minute apatite needles are included in the felspar and also in interstitial isotropic or weakly polarising colourless material, which is probably a felspathic glass.

Olivine basalt [5260, 5261].—These are non-vesicular but porous rocks, rather coarser in grain than the vesicular type. They contain micro-phenocrysts of unaltered olivine set in an intergranular groundmass of pale green and greyish augite with pale violet and greyish violet titan-augite, olivine granules, and plagioclase laths, some of which are zoned from a central core of andesine-labradorite (Ab_{50}) to an outer rim of oligoclase (Ab_{20}). Interstitial yellow-green serpentine [5262], rare iddingsite [5261], apatite needles, granules and plates of iron ores, and turbid glass are also present. A "pipe vesicle" [5258], contains fewer olivine phenocrysts than the average rock, and has larger felspar laths, which are shot through with long apatite needles. Rare xenocrysts of quartz in [5262] and [5263] are surrounded by rims of green augite, and in [5263] the texture is much coarser than usual, in the neighbourhood of the quartz inclusions. There, large skeletal crystals of pale green augite are associated with dendritic platy steel-grey iron ores, and large plagioclase grains. Near the xenocrysts the olivine is iddingsitized, and interstitial brown glass, calcite, and radial aragonite occur.

2. *Gelantipy.*

Most of the described specimens were collected from sections along the Buchan-Woolgulmerang Road. Numbers in parenthesis indicate distances in yards either north (N) or south (S) of the most northerly bridge over Butcher's Creek, about 3 miles south of Gelantipy. Other specimens were obtained from a natural section along Butcher's Creek about a mile north of this bridge.

Porphyritic olivine basalt (1862 S.) [5271].—This is a dense rock containing acicular glassy phenocrysts of plagioclase up to about 5 mm. long, a few amygdales of calcite, and rare turbid phenocrysts of anorthoclase. The plagioclase phenocrysts are labradorite Ab_{35}, and are twinned on the Carlsbad, albite, and pericline laws. A few partially serpentinized micro-phenocrysts of olivine are present, and the groundmass consists of an intergranular aggregate of colourless augite prisms, iron ore grains, and plates and laths of andesine-labradorite, Ab_{50},. Green and smoke-grey glass, the latter full of minute specks of iron ores, fill the interstices, together with a few small apatite needles. The anorthoclase phenocrysts are each composed of an aggregate of distinct individuals, which have evidently passed through a stage when they were not in equilibrium with the magma, as their cores are spongy, containing numerous small inclusions of augite and iron ore grains.

Olivine basalts.—The other basalts from this district are not macroscopically porphyritic, and most of them are dense and fine-grained, containing a few amygdales of calcite. They contain micro-phenocrysts of fresh olivine (550 N. [5267]) or pseudomorphs of serpentine after olivine

(2556 S. [5269]; 3033 S. [5264]) set in an intergranular groundmass of colourless augite granules, basic andesine (Ab_{60-65}) laths, and iron ores. In [5264], which is tachylitic, the mesostasis is a black glass full of specks of black iron ores, and the usual granular or platy iron ores are absent from this rock. In [5267] the glassy mesostasis is pale green, and in [5266] (713 N.) both black and green glass occurs.

[5265] (519 N.) is a vesicular and porous type, similar to the others except that it contains a red to red-brown mineral which is probably iddingsite, although in part it appears to have crystallized directly from the magma, as it has in places a banded colloform structure. A colourless isotropic mineral, of low refractive index, occurs as well defined interstitial grains. This is probably analcite.

The specimens from Butcher's Creek are both olivine basalts, but are richer in olivine than those above described, this mineral occurring both as micro-phenocrysts and as granules in the groundmass. The latter contains prisms of pale green and colourless augite, iron ore grains, and laths of basic andesine (Ab_{55}). In [5268], which is the lower flow at this point, green and yellow-green glass occurs in the mesostasis, while in the upper flow, [5270], the glass is black.

Throughout all the slides interstitial calcite is common, and minute apatite needles and rods occur in the felspars and the mesostasis.

3. *South Buchan.*

All the specimens were collected from a low hill on the west of the South Buchan-road, about 4 miles south of Buchan. Slides [5273-5276] are serpentinized olivine basalts, in which serpentine occurs both as pseudomorphs after olivine and as interstitial patches. The pyroxene is either green or a pale violet titanaugite, and the plagioclase basic labradorite, Ab_{35}. Black glass containing specks of iron ores is common.

No. [5272] is a dense black rock consisting entirely of small iddingsite granules, plagioclase laths (basic labradorite), interstitial pale green serpentine, and black glass, the latter being practically opaque, owing to the crowding of minute specks of iron ore within it.

4. *Seven Creeks, Euroa.*

[5277], from a stony knoll east of the confluence of Wombat Creek and Seven Creeks, and [5278], from the east side of Seven Creeks, about 2 miles downstream from the above, are both limburgitic basalts containing numerous phenocrysts of olivine, marginally iddingsitized, set in a fine-grained intergranular to sub-ophitic groundmass consisting of rods of colourless augite with much interstitial turbid glass and a few ill-defined large plagioclase laths. Large grains of black iron ores are plentiful. [5279], from a hill on the west side of Seven Creeks, in Allotment 27, Gooram Gooram Gong, is a true limburgite consisting of phenocrysts of unaltered olivine and colourless augite, some grains of which, however, have purple margins which are titaniferous. These are set in a dense groundmass consisting of augite rods with interstitial black glass. [5278] is a vesicular type; the others are dense.

REMARKS.

Comparing the above lavas with the petrological types established by Edwards (1938), it will be noted that characteristic Older Volcanic types such as crinanites, ophitic titanaugite dolerites, and nephelinites are absent. The porphyritic olivine-poor basalt from Gelantipy appears to be tholeiitic in nature, although it cannot be established under the microscope that the pyroxenes are pigeonitic, as the grains are too small to enable 2V to be determined.

Iddingsite occurs in both Newer and Older Volcanic rocks, and its presence at all the above localities therefore has little significance. Nevertheless, this mineral is commoner in Newer Volcanic rocks than in Older.

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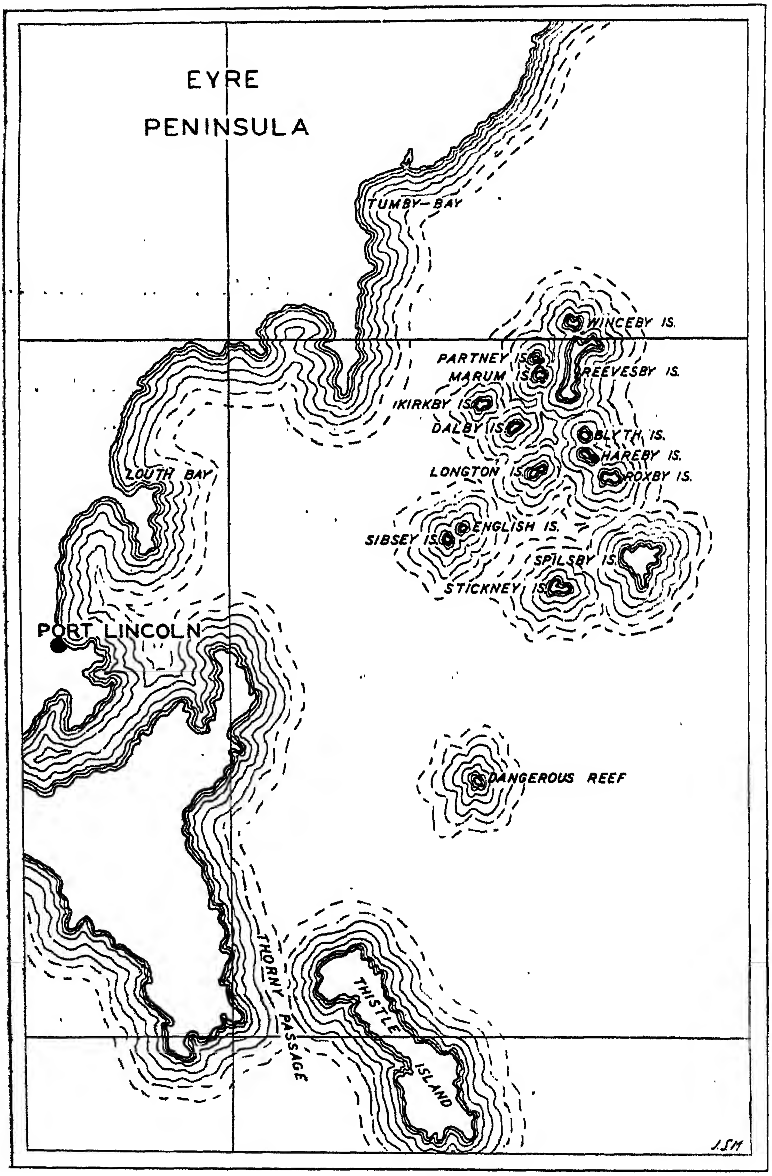
ART. VIII.—THE SIR JOSEPH BANKS ISLANDS.

REPORTS OF THE EXPEDITION OF THE McCOY SOCIETY FOR FIELD INVESTIGATION AND RESEARCH.

PART TWO.

Contents.



The Sir Joseph Banks Islands.

1. *Geology.*

By IRENE E. DEWHURST, B.Sc.

The islands of the Sir Joseph Banks Group are part of Fenner's Spencer-Vincent Sunkland, and have the same geological history as the neighbouring mainland. The islands consist of ancient granites and gneisses capped by travertine and blown sands. Throughout the group the islands are small and low, the highest points being 162 feet on Spilsby, and 91 feet on Reevesby. Most of the following geological notes were made on Reevesby Island.

Reevesby Island originally consisted of three separate islets, which are now connected by sand dunes. Owing to the arid climate and the porous surface deposits no valleys have been cut by streams, and the physiography of the group is governed by the action of wind and waves.

The principal land-forms are sand-dunes and sandy plains. Sand-dunes extend along almost the whole east coast from McCoy Bay to Haystack Bay, but are less continuous on the west coast; low sand-hills practically surround the sand plain on which the camp was situated and form parallel ridges behind the coastal sand-dunes. Except where bound by vegetation, the dunes, particularly the dunes forming the ties, are shifting. Some sand-hills, such as the hill of 60 feet towards the north end of Reevesby Island, are more permanent. The physiography of the other islands is, in general, dominated by blown sand; high sand-hills completely encircle Blyth Island, leaving a sandy hollow in the middle.

Towards the south end of Reevesby are two salt pans occupying areas to which, at one time, the sea had access and deposited salt.

The coastline of the north and south ends of Reevesby Island, is low and rugged; elsewhere are open shallow bays, with long beaches and small projecting headlands or reefs.

Where granites and gneisses outcrop at sea-level, two sets of joints favour the formation of tors and boulders.

Travertine outcropping at sea-level is undercut by the waves, and pot holes and small storm caves are common in this rock.

Low reefs of lateritic ironstone some 7 or 8 square chains in area occur on the west coast of the south end of Reevesby Island, and also off Roxby Island.

The coast is shelving, and at low tide the sea recedes 20 or 30 yards. On the west coast of Reevesby, a sand spit extending south-westerly from Middle Rocks has been formed by currents sweeping sands from the north. Moreton Bay is fast being silted up.

The following series of formations is found:—

1. *Recent Sands.*—Coastal dunes and loose sands extending inland, formed of granitic detritus and comminuted shells.

2. *Older Sand-hills.*—Friable dune rock formed by consolidation of similar sands. Recent shells, very little altered, were found in a small excavation in this rock near the camp.

3. *Travertine.*—More or less massive limestone, fairly pure to coarse and sandy; bedded, concretionary or nodular; it generally rests immediately upon the ancient granite-gneiss complex. A cliff 15 to 20 feet high at the south end of Reevesby Island gives the following section:—

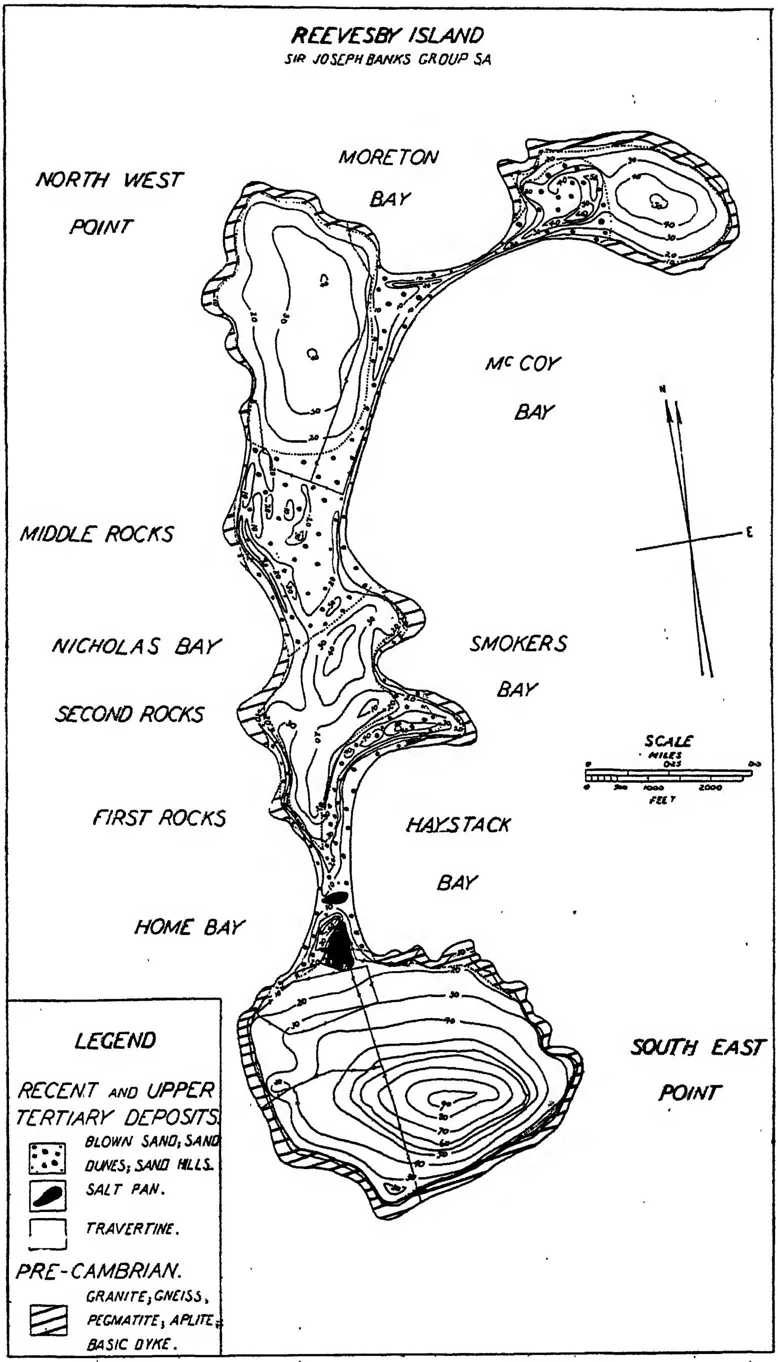
- (i) Red clay with buckshot, 3 feet (base).
- (ii) Impure reddish travertine passing up to white, nodular travertine, 7 feet.
- (iii) Sandy travertine, 3 feet.
- (iv) Red travertine soil, 2 feet (top).

The section apparently represents two phases; the first (i, ii) followed after an interval by a second (iii, iv).

4. *Lateritic Ironstone.*—Thin beds exposed as reefs at low tide. They rest immediately on granitic rocks, from which they have been formed by weathering. The lateritic ironstone consists of felspar (5 per cent.), biotite (10 per cent.), limonite and haematite (20–30 per cent.), cliachite (50 per cent.) in about the proportions shown, and is associated with bauxite and common ironstone. Elsewhere it is replaced by ferruginous grit consisting of siliceous grains cemented by iron oxide.

5. *The Pre-Cambrian Complex.*—The granite-gneiss complex seldom outcrops except on the coast. The rock types are:—

- (i) *Norite.*—Forms dark-coloured dense "basic dykes" and patches in the granites. The rock consists of plagioclase, a little orthoclase, pyroxenes (hypersthene and a little diopside) biotite, accessory augite, magnetite and ilmenite.
- (ii) *Pegmatite and Aplite.*—Plentiful dykes, veins and tongues. Some pegmatites are extremely coarse grained mixtures of massive pink felspar and blue to white quartz. The aplites, usually pink are fine, even grained, saccharoid rocks consisting of quartz, plagioclase (sericitized), minor orthoclase, microcline, myrmekite, muscovite, biotite (chloritized), with a little magnetite and ilmenite altering to leucoxene. Occasionally mortar structure has been developed.
- (iii) *Granites.*—Coarse-grained throughout, red or grey in colour, frequently gneissic. The gneissic types are generally porphyritic.



Geology of Reevesby Is.—Field work by Alan Gordon and Irene E. Dewhurst.

(iv) *Acid Gneisses*:—

(*a*) Augen Gneiss.—Very abundant. The augens are mainly of felspar. The rock consists of quartz with undulose extinction, felspars (microcline, les abundant orthoclase, microperthite and oligoclase), biotite (with inclusions of apatite and zircon), magnetite (altered to haematite), ilmenite (altered to leucoxene). Quartz and orthoclase form symplektitic intergrowths, and the oligoclase contains vermicular inclusions of quartz.

(*b*) Biotite-Granite Gneiss.—A normal type composed of felspar, quartz, and biotite.

(*c*) Granulite.—Less common. An even-grained, granular rock consisting of hornblende, hypersthene, less abundant biotite, quartz, plagioclase, and small grains of ilmenite.

(v) *Basic Gneiss*.—A dark-grey amphibolite, sometimes schistose, occurring both in irregular patches and in definite bands in the acid gneisses. The bands have their longer axes parallel to the foliation in the gneiss (Pl. 8, f. 1).

Wade and others consider that these gneisses represent metamorphosed limestones.

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Explanation of Plates.

Fig. 1.—Relationship of Acid gneiss (g), norite (n), aplite (ap.) and amphibolite (a).

Fig. 2.—Channel formed by weathered "basic dyke".

Fig. 1.

Fig. 2.

2. *Survey of the Vegetation Community on Reevesby Island.*

By R. H. HAYMAN, B.Agr. Sc. and E. E. HENTY, B.Agr. Sc.

The survey was made over a period of three weeks in January, 1937. The accompanying map shows the main vegetation communities observed during that time. It was noted that each community was largely confined to its own soil type; the map could therefore be used as a rough soil map also.

The soils are predominantly sandy in character, varying from a shallow red sandy loam over travertine limestone at a depth of 3-6 inches to a white sandy loam over travertine, or deep white sand on the dunes.

The vegetation of the island is divided into four communities:—

1. The saltbush plain.
2. The *Myoporum-Olearia* community.
3. The sand dunes.
4. The salt pans.

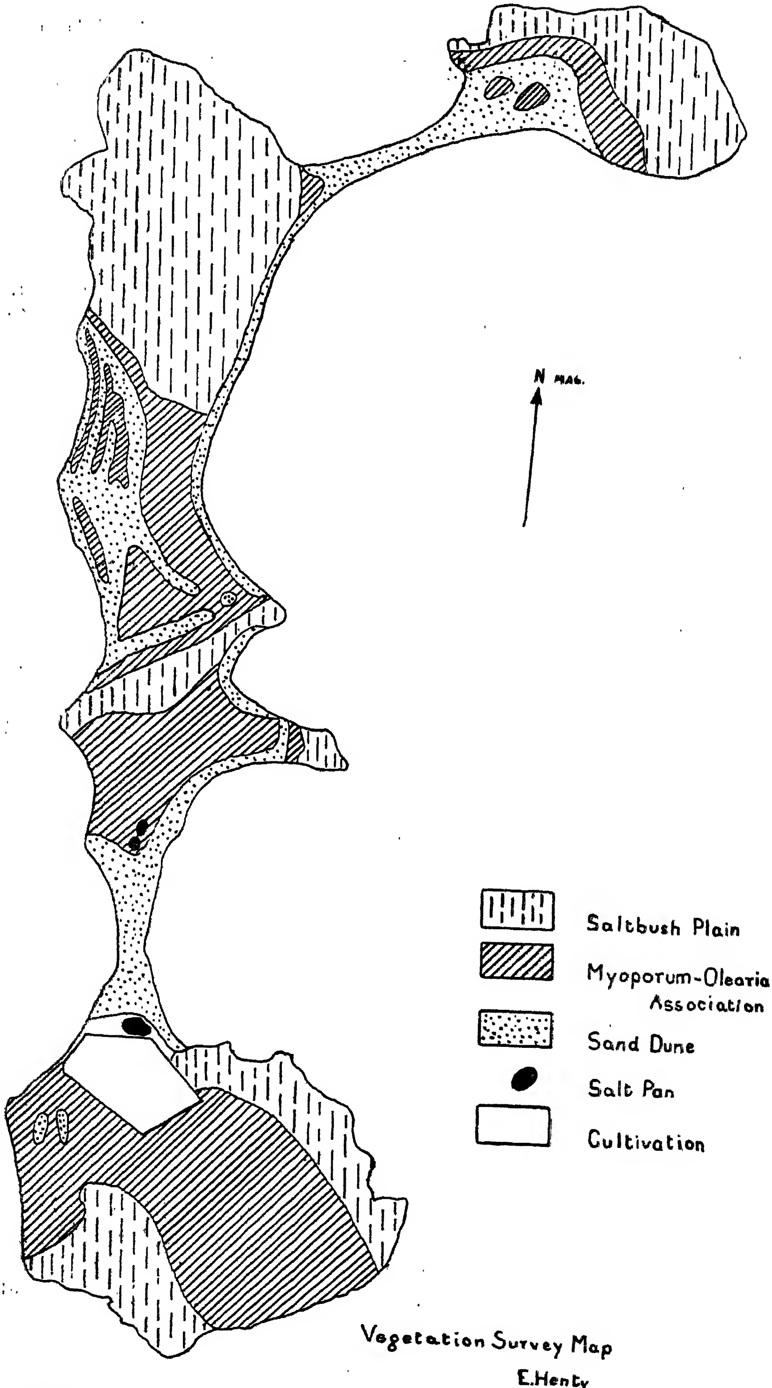
1. The Saltbush Plain.

This occupies about one-third of the area of the island, chiefly towards the northern end, and is typical of the shallow red sandy soils. The dominant plant is *Atriplex paludosum,* which grows in roughly circular patches ranging in diameter from 4-10 feet. In many cases the centres of the patches are dead, leaving an annulus of green material; this is possibly due to the grazing and trampling of sheep which are kept on the island. *Atriplex Muelleri* and *Rhagodia crassifolia* occur to some extent; *Lycium australe* is a feature of the higher and more barren parts of the community; and stunted bushes of *Myoporum insulare* are scattered throughout the area. All the shrubs are fairly well separated, giving an open community. Grasses and herbaceous annual plants are little in evidence at this time of the year, except *Pelargonium australe,* which is widespread. The only grasses still green at this time are *Festuca rigida, Lepturus incurvatus, Danthonia semi-annularis* and *Stipa scabra.* Residues of many other grasses, including *Hordeum murinum, Festuca bromoides, Koeleria phleoides* and several species of Stipas, are also present, indicating an abundant gramineous flora during the rainy season. *Mesembrianthemum australe* is widespread, and *M. crystallinum* is also present where the original saltbush has been destroyed. Burrs of *Medicago denticulata* are also common.

2. The Myoporum-*Olearia* community.

Olearia axillaris is dominant and *Calocephalus Brownii* subdominant on the small plains along the sand dunes on the west side of the island. On the deep soil near the dunes and on the fringe of the saltbush plains *Myoporum insulare* becomes

REEVESBY ISLAND



dominant, though in the latter place the shrubs are very stunted. The distribution of the *Olearia* is apparently affected by the depth of the soil, and its range is more limited than *Myoporum*, as it is absent where the soil is shallow along the edge of the saltbush plain, and also where the soil deepens along the edge of the sand dunes, *Myoporum* assuming the dominance in each case.

In the complex the *Myoporum* grows to a height of about 12 feet and is generally covered by the trailing *Muehlenbeckia adpressa* which is a feature of the community. *Olearia axillaris* and *O. ramulosa* grow to a height of 5-7 feet. Two stunted trees of *Casuarina stricta*, five specimens of *Eucalyptus angulosum* and several specimens of *Acacia rupicola* are present. This is by far the tallest association on the island.

3. The Sand Dunes.

Sand dunes occur along most of the eastern foreshore, in the west central part of the island, and on the two narrow necks to the north and south of the island.

Vegetation on the dunes is very scattered; *Myoporum insulare* is the main plant, and *Muehlenbeckia adpressa* accompanies it. In several places *Atriplex cinereum* is present as large shrubs. *Spinifex hirsutus* is present in isolated patches, and *Ammophila arenaria* and *Lolium rigidum* are also to be found.

The dunes along the east coast show signs of moving inland; along their inner edges are clear indications that the scrub is being covered over (Pl. IX., fig. 1).

4. The Salt Pans.

The vegetation is here composed mainly of *Suaeda australis* and *Arthrocnemum halocnemoides* var. *pergranulatum*, interspersed with large areas of vacant ground. The pans consist of an impermeable layer of clay and are flooded after rain. Salt crystals occur on the surface.

General.

The climate of the island is semi-arid with winter rain. The rainfall of the adjacent mainland is 15 inches approximately, and the 15-in. isohyet passes through the group of islands. The perennial plants are either xerophytic or succulent, while the annuals are true mesophytes with a winter growing period, maturing before the summer drought sets in.

Variation in the vegetation seems to be due almost entirely to edaphic factors, the climate being uniform over such a small area, while aspect, as a factor, is largely eliminated by the flat nature of the island.

Atriplex paludosum grows only on the shallow red sandy soil; *Myoporum insulare* on all soils, but less effectively on the shallow soil; *Olearia axillaris* is restricted to those areas where there is only about 12 inches of soil above the travertine; and *Atriplex cinereum* to the deep sand.

Explanation of Plates.

PLATE IX.

Fig. 1.—Typical *Myoporum-Olearia* community. In the left foreground a sand dune is seen moving inland and covering an *Olearia* shrub.

Fig. 2.—Small plain among sand dunes, showing the dominance of the *Olearia*.

PLATE X.

Fig. 1.—Typical sand dunes and their vegetation.

Fig. 2.—Typical salt pan; *Myoporum-Olearia* community in the foreground, sand dunes in the rear.

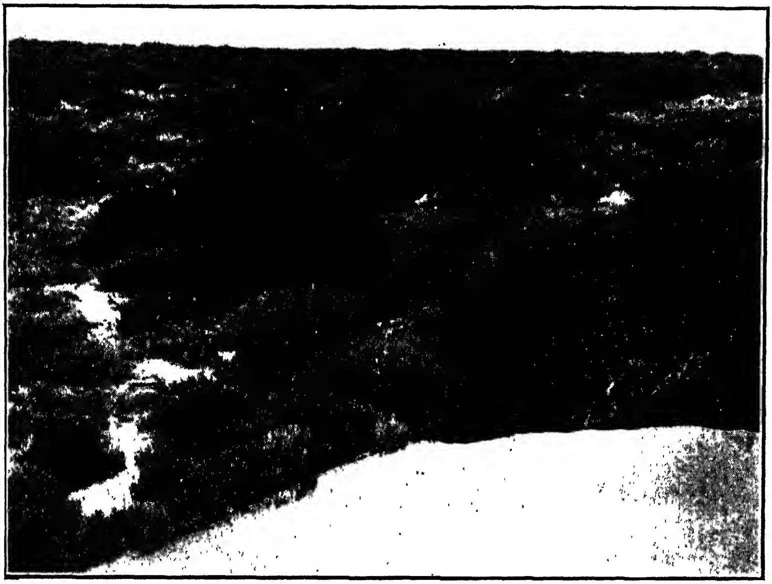


Fig. 1.

Fig. 2.

FIG. 1.

FIG. 2.

3. *Lichens.*

By ETHEL M. SHACKELL, M.Sc.

All forms collected are well known Southern Australian species. They occurred commonly on the rocks around the sea fronts of the islands, some spreading inland on rocks or dead wood. Two species are confined to inland localities where they were found on Austral Box Thorn (*Lycium australe*). Weathering of the crustaceous species was pronounced on the exposed rock surfaces, the older central regions of the thallus being disintegrated by repeated swelling and contracting of the deeply areolated plant body in response to alternating wet and dry conditions. Particles of the thallus thus become easily dislodged, leaving bare places in the centre of the thallus. These patches may become recolonized in time, either by the same lichen or by an invading species.

The classification follows Fink (The Lichen Flora of the United States, 1935, pp. 1-426).

Class ASCOLICHENES.

Subclass GYMNOCARPEAE.

Order CALICIALES.

Family CALICIACEAE.

MYCOCALICIUM PARIETINUM (Acharius, 1816).

Calicium parietinum Ach., Kgl. Vetensk.-Akad. Nya. Handl. 1816, p. 260, pl. 8, f. 1 a-b.

Mycocalicium parietinum (Ach.), Wainio, Etud. Lich. Bres., II., 1890, p. 182.

On dead wood at Reevesby Island.

Order LECANORALES.

Family PERTUSARIACEAE.

PERTUSARIA NOLENS Nylander, 1864.

Pertusaria nolens Nyl., Flora XLVII., 1864, p. 489.

On granitic rocks at Winceby, Langdon, Kirkby, Reevesby, Hareby, Marram, and Stickney Islands.

Family PARMELIACEAE.

PARMELIA LIMBATA (Laurer, 1833).

Parmelia limbata (Laur.) Shirley, Lichen Flora of Queensland, 1890, p. 46.

On granitic rocks and dead wood at Langdon, Reevesby, and Stickney Islands.

Family USNEACEAE.

Ramalina fraxinea (Linn., 1753).

Lichen fraxineus Linn. Species Plantarum, 1753, pp. 1146, 1147.
Ramalina fraxinea (Linn.), Ach., Lichenographia Universalis, 1810, p. 122, pl. 13, f. 5-11.

On *Lycium australe* at Reevesby Island.

Family TELOSCHISTACEAE.

Teloschistes villosus (Acharius, 1803).

Parmelia villosa Ach., Meth. Lich., 1803, p. 254.
Teloschistes villosus (Ach.), Norman, Nyt. Mag. Naturv., VII., 1852, p. 229.

On *Lycium australe* at Reevesby Island.

Teloschistes polycarpus (Ehrhart, 1798).

Lichen polycarpus Ehrh., in Ach. Lich. Suec., 1798, p. 135.
Teloschistes polycarpus (Ehrh.), Tuckerman, Syn. N. A. Lich., I., 1882, p. 50.

On granitic rocks and wood at Winceby, Langdon, Kirkby, Reevesby, Hareby, Marram, Little English, and Stickney Islands.

4. *Mollusca, Part 2; General.*

By BERNARD C. COTTON, South Australian Museum.

During December 1936, by invitation of the McCoy Society, the author visited the Banks Group, Spencer Gulf, and collected Mollusca. Part I. of this paper (Proc. Roy. Soc. Vic. I. (n.s.) pt. II. 1938) describes the spermatophore of *Rossia australis* Berry from specimens taken at Reevesby Island; the present paper, Part II., gives a list of species obtained, erects one new genus, one new subgenus, and describes eight new species.

Localities are indicated as follows:—Loc. 1, Reevesby Island, west beach; Loc. 2, Reevesby Island, north beach; Loc. 3, Reevesby Island, east beach; Loc. 4, Reevesby Island, south beach; Loc. 5, Lusby Island; Loc. 6, English Island; Loc. 7, Winceby Island.

Class PELECYPODA.

Family SOLEMYIDAE.

SOLEMYA AUSTRALIS Lamarck, 1818.

Solemya australis Lamk., Anim. S. Vert., V., 1818, p. 489.

Loc. 1; two specimens.

Family ARCIDAE.

BARBATIA PISTACHIA (Lamarck, 1819).

Arca pistachia Lamk., Anim. S. Vert., VI., 1819, p. 41.
Barbatia pistachia (Lamk.), Cotton, Rec. S. Aust. Mus., IV., 2, 1930, p. 228

Loc. 1; numerous.

BARBATIA LAMINATA (Angas, 1865).

Arca laminata Angas, P.Z.S., 1865, p. 655.
Barbatia laminata (Angas), Cotton, Rec. S. Aust. Mus., IV., 2, 1930, p. 228.

Loc. 1; one specimen dredged alive in three fathoms.

Family LIMOPSIDAE.

LIMOPSIS FORTERADIATUS Cotton, 1930.

Limopsis tenisoni forteradiatus Cotton, Rec. S. Aust. Mus., IV., 2, 1930, p. 231.

Loc. 1, 2; two dead specimens, probably subfossil. Fairly common on South Australian raised beaches; less common on ordinary beaches but abundant at 10 fathoms.

Family GLYCYMERIDAE.

Glycymeris radians (Lamarck, 1819).

Pectunculus radians Lamk., Anim. S. Vert., VI., 1819, p. 54.

Loc. 1; twelve specimens.

Family VULSELLIDAE.

Malleus meridianus Cotton, 1930.

Malleus meridianus Cotton, Rec. S. Aust. Mus., IV., 2, 1930, p. 232.

Loc. 1, 2, 3, 4; numerous.

Family PTERIIDAE.

Electroma georgiana (Quoy & Gaimard, 1835).

Avicula georgiana Q and G., Voy. de L'Astrol, III., 1835, p. 457, pl. 77, f. 10, 11.

Loc. 1, 2; numerous.

Family PINNIDAE.

Pinna dolabrata Lamarck, 1819.

Pinna dolabrata Lamk., Anim. S. Vert., VI., 1819, p. 133.

Loc. 1, 3; numerous at low tide mark, with chitons attached.

Family OSTREIDAE.

Ostrea sinuata Lamarck, 1819.

Ostrea sinuata Lamk., Anim. S. Vert., VI., 1819, p. 208.

Loc. 1, 2, 3; odd dead specimens.

Family TRIGONIIDAE.

Neotrigonia bednalli (Verco, 1907).

Trigonia bednalli Verco, Tr. R. Soc. S. Aust., XXXI., 1907, p. 213, pl. 28, f. 1-3.

Loc. 1; two eroded valves.

Family PECTINIDAE.

Notovola alba (Tate, 1887).

Pecten fumatus albus Tate, Pr. R. Soc. Tasm., 1887, p. 113.

Loc. 1, 2.

Equichlamys bifrons (Lamarck, 1819).

Pecten bifrons Lamk., Anim. S. Vert., VI., 1819, p. 164.

Loc. 1, 2, 6.

SCAEOCHLAMYS AKTINOS (Petterd, 1885).

Chlamys aktinos, Pett., Pr. Roy. Soc. Tasm., 1885, p. 320.

Loc. 1; one specimen.

MIMACHLAMYS ASPERRIMUS (Lamarck, 1819).

Pecten asperrimus Lamk., Anim. S. Vert., VI., 1819, p. 174.

Loc. 1, 2, 3, 4, 5, 6.

Family SPONDYLIDAE.

SPONDYLUS TENELLUS Reeve, 1856.

Spondylus tenellus Reeve, Conch. Icon., IX., 1856, pl. 18, f. 67.

Loc. 1, 2, 3; numerous, up to 75 mm. in diameter.

Family LIMIDAE.

AUSTRALIMA GEMINA Iredale, 1929.

Australima nimbifer gemina Ird., Rec. Aust. Mus., XVII., 4, 1929, p. 165.

Loc. 1; two specimens.

MANTELLUM ORIENTALE (Adams & Reeve, 1850).

Lima orientalis A. & R., Zool. Samarang, 1850, p. 75, pl. 11, f. 33.

Loc. 1.

LIMATULA STRANGEI (Sowerby, 1872).

Lima strangei Sow., Conch. Icon., XVIII., 1872, pl. III., f. 15.

Loc. 1; one specimen.

Family ANOMIIDAE.

MONIA IONE (Gray, 1850).

Placuanomia ione Gray, P.Z.S., 1850, p. 123.

Loc. 1, 3.

Family MYTILIDAE.

MODIOLUS AREOLATUS Gould, 1850.

Modiolus areolatus Gould, Pr. Boston Soc. Nat. Hist., III., 1850, p. 343.

Loc. 1, 2, 3.

BRACHYODONTES EROSUS (Lamarck, 1819).

Mytilus erosus Lamk., Anim. S. Vert., VI., 1819, p. 120.

Loc. 1, 2, 3, 4; a bed of these mussels is situated off the S.W. coast of Reevesby Island; depth one fathom.

BRACHYODONTES HIRSUTUS (Lamarck, 1819).

Mytilus hirsutus Lamk., Anim. S. Vert., VI., 1819, p. 120.

Loc. 1, 2, 3, 6.

MUSCULUS NANUS (Dunker, 1856).

Lanistina nanus Dunk., P.Z.S., 1856, p. 365.

Loc. 1; two examples.

Family CLEIDOTHAERIDAE.

CLEIDOTHAERUS ALBIDUS (Lamarck, 1819).

Chama albida Lamk., Anim. S. Vert., VI., 1819, p. 96.

Loc. 1, 3.

Family CLAVAGELLIDAE.

CLAVAGELLA MULTANGULARIS (Tate, 1886).

Aspergillum multangularis Tate, Pr. R. Soc. S. Aust., 1886, p. 64.

Loc. 1; four examples.

Family CRASSATELLIDAE.

EUCRASSATELLA VERCONIS Iredale, 1936.

Eucrassatella kingicola verconis Ird., Rec. Aust. Mus., Vol. XIX., 5, 1936, p. 271.

Loc. 1, 2, 3, 4.

Family CARDITIDAE.

CARDITA CRASSICOSTATA Lamarck, 1819.

Cardita crassicostata Lamk., Anim. S. Vert. VI., 1819, p. 24.

Loc. 1; rather common, large.

Family CHAMIDAE.

CHAMA RUDERALIS Lamarck, 1819.

Chama ruderalis Lamk., Anim. S. Vert., VI., p. 96, 1819.

Loc. 1; two specimens.

Family LEPTONIDAE.

EPHIPPODONTA MACDOUGALLI Tate, 1888.

Ephippodonta macdougalli Tate, Tr. R. Soc. S. Aust., XI., 1888, p. 64, pl. XI., f. 5*a*-*b*.

Loc. 3; under large stones on reef at low tide; one alive. Not previously recorded from Spencer Gulf. A series from Port Lincoln show obscure secondary concentric sculpture which bridges the radials. One specimen is bright pink.

EPHIPPODONTA LUNATA (Tate, 1886).

Scintilla (?) *lunata* Tate, Tr. R. Soc. S. Aust., IX., 1886, p. 69, pl. IV., f. 8.

Loc. 3; under large stones on reef at low tide. The granose sculpture separates from the shell very easily, leaving a smooth surface. Some examples differ from the typical *lunata* in being consistently smooth and more solid, and in having a smaller, sharper umbo and well defined brown radial flames. One specimen is bright pink.

Family CARDIIDAE.

CARDIUM RACKETTI Donovan, 1826.

Cardium racketti Don., Nat. Repository, IV., 1826, p. 125.

Loc. 1, 4; specimens from Loc. 1 measure up to 46 mm. in height.

CARDIUM ERUGATUM Tate, 1888.

Cardium erugatum Tate, Tr. R. Soc. S. Aust., XI., 1888, p. 62, pl. XI., f. 6.

Loc. 1, 4; one specimen from each locality. Hitherto taken only from Southern York Peninsula.

Family VENERIDAE.

CALLANAITIS DISJECTA (Perry, 1811).

Venus disjecta Perry, Conchology, pl. 58, f. 3, 1811.

Loc. 1; three odd valves.

TAWERA GALLINULA (Lamarck, 1818).

Venus gallinula Lamk., Anim. S. Vert., V., 1818, p. 592.

Loc. 1, 3; numerous, large.

KATELYSIA SCALARINA (Lamarck, 1818).

Venus scalarina Lamk., Anim. S. Vert., V., 1818, p. 508.
Katelysia corrugata (Lamk.), Cotton, Rec. S. Aust. Mus., V., 1934, p. 173.

Loc. 2; numerous, small.

VENERUPIS GALACTITES (Lamarck, 1818).

Venus galactites Lamk., Anim. S. Vert., V., 1818, p. 599.

Loc. 1; apparently the dominant bivalve in this locality.

Family TELLINIDAE.

PSEUDARCOPAGIA VICTORIAE Gatliff & Gabriel, 1914.

Pseudarcopagia victoriae G. and G., Vict. Nat. XXXI., 5, 1914, p. 83.

Loc. 1; one specimen.

Family PSAMMOBIIDAE.

PSAMMOBIA LIVIDA Lamarck, 1818.

Psammobia livida Lamk., Anim. S. Vert., V., 1818, p. 515.

Loc. 1; four specimens.

SOLETELLINA BIRADIATA (Wood, 1815).

Solen biradiata Wood, General Conch., 1815, p. 135, pl. 33, f. 1.

Loc. 1, 2; at Loc. 2, on sand flats and about 16 inches below surface, alive.

Family MACTRIDAE.

MACTRA PURA Deshayes, 1853.

Mactra pura Desh., P.Z.S., 1853, p. 15.
Mactra (Telemactra) abbreviata Lamk., Cotton, Rec. S. Aust. Mus., V., 1934, p. 176.

Loc. 1; numerous, large.

MACTRA AUSTRALIS Lamarck, 1818.

Mactra australis Lamk., Anim. S. Vert., V., 1818, p. 475.

Loc. 1; four specimens.

ANAPELLA PINGUIS (Crosse & Fischer, 1864).

Mactra pinguis, C. and F., J. de Conch., XII., 1864, p. 349.
Anapella cycladea Lamk., Cotton, Rec. S. Aust. Mus., V., 1934, p. 176.

Loc. 1; one specimen.

LUTRARIA RHYNCHAENA Jonas, 1844.

Lutraria rhynchaena Jonas, Zeit. f. Malak., I., 1884, p. 34.

Loc. 1, 2, 4.

Family AMPHIDESMATIDAE.

AMPHIDESMA CUNEATA (Lamarck, 1818).

Crassatella cuneata Lamk., Anim. S. Vert., V., 1818, p. 843.

Class CEPHALOPODA.

Family SPIRULIDAE.

SPIRULA SPIRULA (Linne, 1758).

Nautilus spirula Linne, Syst. Nat., ed. X., 1758, p. 710.

Loc. 1; three specimens.

Family SEPIIDAE.

MESEMBRISEPIA CHIROTREMA (Berry, 1918).

Sepia chirotrema Berry, "Endeavour" Biol. Res., IV., 1918, p. 268, pl. LXXIV., f. 3-9, pl. LXXV.-LXXVII.

Loc. 1; two fragments.

MESEMBRISEPIA NOVAEHOLLANDIAE (Hoyle, 1909).

Sepia novae, hollandiae Hoyle, Pr. R. Phys. Soc. Edin. XVII., 1909, p. 266.

Loc. 1, 2, 3, 4; numerous.

ARCTOSEPIA BRAGGI (Verco, 1907).

Sepia braggi Verco, Tr. R. Soc. S. Aust., XXI.. 1907, p. 213, pl. XXVII., f. 6 a-d.

Loc. 1; four specimens. First record for Spencer Gulf.

AMPLISEPIA APAMA (Gray, 1849).

Sepia apama Gray, Cat. Moll. Brit. Mus. (Cephalopoda), 1849, p. 103.

Loc. 1, 2, 3, 4; fairly numerous.

Family ARGONAUTIDAE.

ARGONAUTA NODOSA Solander, 1786.

Argonauta nodosa Solander, Portland Cat., 1786, p. 76.

Loc. 2.

Family SEPIOLIDAE.

ROSSIA AUSTRALIS Berry, 1918.

Rossia australis Berry, "Endeavour" Biol. Res.. IV., 1918, p. 253, pl. XIX., f. 3, 4, pl. LXX.

Loc. 1; two juvenile females and one male taken at a depth of 4 feet over a mussel (*B. erosus*) bed. Spermataphore described in previous part of this report.

Family OCTOPODIDAE.

OCTOPUS AUSTRALIS Hoyle, 1885.

Octopus australis Hoyle, Ann. Mag. Nat. Hist. (5), V., 1885, p. 224.

Loc. 1; four females netted in shallow water. The central area of the dorsal surface is edged with white and has a narrow, light brown strip on either side; specimens from Gulf St. Vincent have a uniformly brown dorsal surface. Ventral surface yellowish white; arms light brown on outer, yellowish white on inner surface; body and outer base of arms fairly granular.

Family LOLIGINIDAE.

SEPIOTEUTHIS AUSTRALIS Quoy & Gaimard, 1824.

Sepioteuthis australis Q. and G., Voy. de L'Astrolabe, Zool. II., 1832, p. 77, pl. IV., f. 1.

Loc. 1, 2, 3, 4, 5, 6, 7; plentiful.

Class LORICATA.

Family ISCHNOCHITONIDAE.

ISCHNOCHITON LINEOLATUS (Blainville, 1825).

Chiton lineolatus Bl., Dict. Sci. Nat., XXXVI., 1825, p. 541.

Loc. 1, 3; numerous specimens under weed-covered rocks at extreme low tide.

ISCHNOCHITON VARIEGATUS (Adams & Angas, 1864).

Lepidopleurus variegatus A. and A., P.Z.S., 1864, p. 192.

Loc. 1, 3; numerous on rocks at low tide, but at a higher level than *I. lineolatus*.

ISCHNOCHITON CONTRACTUS (Reeve, 1847).

Chiton contractus Reeve, Conch. Icon., IV., 1847, pl. XV., f. 78.
Ischnochiton decussatus Pilsbry, Nautilus VIII., 1895, p. 129.

Loc. 1, 7; on rocks adjacent to Posidonia beds.

ISCHNOCHITON CARIOSUS (Dall, 1878).

Heterozona cariosa Dall, Proc. U.S. Nat. Mus., 1878, p. 331.
Anisoradsia mawlei saundersi Ashby, Tr. R. Soc. S. Aust., XLII., 1918, p. 82.

Loc. 1, 3.

ISCHNOCHITON VIRGATUS (Reeve, 1847).

Chiton virgatus Reeve, Conch. Icon., IV., 1847, pl. XXVIII., f. 192.

Loc. 3; in shallow pools.

Family PLAXIPHORIDAE.

PONEROPLAX COSTATA (Blainville, 1825).

Chiton costatus Bl., Dict. Sci. (Levrault), XXXVI., 1825, p. 548.

Loc. 3; one taken at high tide mark.

Family CHITONIDAE.

ANTHOCHITON EXOPTANDUS (Bednall, 1897).

Chiton exoptandus Bedn., Pr. Mal. Soc., II., 1897, p. 152, text f. and pl. XII., f. 7.

One juvenile attached to *Pinna dolabrata* Lk., dredged in four fathoms off N.W. of Reevesby Island.

Family CRYPTOPLACIDAE.

CRYPTOPLAX STRIATA (Lamarck, 1819).

Chitonellus striatus Lamk., Anim. S. Vert., VI., 1819, p. 317.

Loc. 1; dredged in shallow water.

Class GASTROPODA.

Family HALIOTIDAE.

HALIOTIS (NOTOHALIOTIS) IMPROBULUM Iredale, 1924.

Haliotis naevosum improbulum Iredale, Proc. Linn. Soc. N.S.W. XLIX., pt. 3, p. 222, 1924.

Loc. 1, 2, 4; common.

HALIOTIS (NEOHALIOTIS) EMMAE (Gray, 1846).

Haliotis emmae Gray, Reeve Conch. Icon., III., 1846, pl. 10, f. 29.

Loc. 1, 2. 4.

HALIOTIS (NEOHALIOTIS) SCALARIS (Leach, 1814).

Padollus scalaris Leach, Zool. Miscell., I., 1814, p. 66, pl. 28.

Loc. 1, 2; two specimens. Closely allied to *N. emmae*.

HALIOTIS (EXOHALIOTIS) CYCLOBATES (Peron, 1816).

Haliotis cyclobates Peron, Voy. Terr. Aust., II., 1816, p. 8.

Loc. 1, 2, 3, 4.

Family FISSURELLIDAE.

SCUTUS ANATINUS (Donovan, 1820).

Patella anatinus Don., in Ree's Encyclop. Conch., 1820, pl. XVI.

Loc. 1, 2; large specimens on reefs at extremely low tide.

TUGALI CICATRICOSUS (Adams, 1851).

Tugalia cicatricosa Adams, Thes. Conch., III., 1863, p. 222, pl. 219, f. 14.

Loc. 2; one live specimen.

Family PATELLIDAE.

CELLANA RUBRAURANTIACA (Blainville, 1825).

Patella rubaurantiaca Bl., Dict. Sci. Nat. (Levrault), XXXVIII., 1825, p. 110.

Helcioniscus limbatus Philippi, Abbild. und Besch. Conch., III., p. 71, pl. III., f. 2, 1849.

Loc. 2; on rocks, large, typical.

CELLANA TRAMOSERICA (Sowerby, 1825).

Patella tramoserica Sow., Cat. Shells Tankerville, 1825, p. 30.

Patella variegata Bl., Dict. Sci. Nat. (Levrault), XXXVIII., 1825, p. 101.

Loc. 1, 2; on rocks, common.

Family LOTTIIDAE.

PATELLOIDA ALTICOSTATA (Angas, 1865).

Patella alticostata Angas, P.Z.S., 1865, p. 56, pl. II., f. 11.

Loc. 2; fairly common.

Family TROCHIDAE.

Clanculus (Isoclanculus) weedingi sp. nov.

(Pl. vii., fig. 2.)

Depressedly conoid, thick, falsely umbilicate, dark reddish blue, last whorl with four equal granulose lirae on the upper part of the whorl and five on the base; whorls five, first eroded whitish, the last rapidly descending towards the aperture which is somewhat contracted, outer lip denticulate within, a larger denticle above and below, the lower one separated by a notch from the basal tubercle of the columella.

Holotype; height 9 mm., diam. 11.5 mm.; Reevesby Island (Reg. No. D.13304, S.A. Museum).

Well known to South Australian collectors for many years. The Rev. Weeding took good specimens at Port Hughes.

In size, shape and regularity of the sculpture it is quite distinct from its nearest ally *C.* (*I.*) *dunkeri,* and differs from *C.* (*I.*) *yatesi* in the rounded whorls and spaced granulose spiral lirae. At a casual glance this species has a marked resemblance to *Micrastraea rutidoloma* in size, shape, and sculpture, but it is quite distinct in the clanculoid aperture features.

Loc. 1; two specimens in shell sand.

Austrocochlea torri Cotton and Godfrey, 1934.

Austrocochlea torri C. and G., S. Aust. Nat., Vol. XVI. (1), 1934, pl. 1.

Loc. 1, 2, 3, 4, 5, 6, 7; on rocks.

Austrocochlea concamerata (Wood, 1828).

Trochus concamerata Wood, Index Test., suppl. 1828, pl. 6, f. 35.

Trochus striolatus Quoy and Gaimard, Zool. de L'Astrolabe, III., 1834, p. 253, pl. 63, f. 18, 22.

Loc. 1, 2, 3, 4, 5, 6, 7; on rocks at low time.

Family STOMATELLIDAE.

Stomatella imbricata Lamarck, 1816.

Stomatella imbricata Lamk., Encycl. Meth., 1816, p. 10, pl. 450, f. 2.

Loc. 2, 4, 5; on rocks.

Herpetopoma annectans (Tate, 1893).

Euchelus annectans Tate, Tr. R. Soc. S. Aust., XVII., 1893, p. 196.

Loc. 1; in shell sand.

Family TURBINIDAE.

Turbo (Subninella) undulatus (Martyn, 1784).

Limax undulatus Martyn, Univ. Conch., 1784, f. 29.

Loc. 2; one fragment.

TURBO (NINELLA) TORQUATUS (Gmelin, 1784).

Turbo torquatus, Gmel., Syst. Nat. Bed., p. 3597, No. 106.
Limax stamineus Martyn, Univ. Conch., 1784, p. 71.

Loc. 2, 6; broken shells on flat rocks, evidently dropped and broken by the Pacific Gull.

TURBO (EUNINELLA) GRUNERI Philippi, 1846.

Turbo gruneri Phil., Conch. Cab., 1846, p. 52, pl. 12, f. 7. 8.

Loc. 1; four specimens.

Not previously assigned to a subgenus; the new subgenus *Euninella*, here introduced for *T. gruneri*, differs from other subgenera of *Turbo* as follows. Operculum paucispiral with smooth outer surface, resembling those of *T.* (*Subninella*) *undulatus* and *T.* (*Dinassovica*) *jourdani*, with curved, ear-like processes like those of *T.* (*Ninella*) *torquatus*, but much less valid; shell imperforate like that of *jourdani*, which also has a tendency to spiral ribbing when juvenile. The new subgenus seems to have affinities with the subgenus *Dinassovica*, but is distinguished by the differences noted above.

TURBO (DINASSOVICA) JOURDANI Kiener, 1839.

Turbo jourdani Kiener, Rec. Zool. Soc. Cuvier, 1839, p. 324.
Dinassovica verconis Iredale, Pr. Zool. Soc. N.S.W., VIII., pl. 4, 1937, p. 247.

Examination of a series of Western Australian and South Australian specimens convinces me that *verconis* Iredale, is merely a variant of *jourdani.*

Loc. 2; a complete shell 170 mm. high, 150 mm. wide.

BALLASTRAEA SQUAMIFERA (Koch, 1844).

Turbo squamiferus Koch, Philippi, Abbild., I., 1844, p. 138, pl. 4, f. 9.

Loc. 1, 2; numerous.

MICRASTRAEA gen. nov.

Shell small, depressed, solid, imperforate; whorls five, plicate at the sutures, the folds fainter and usually bifurcating near the periphery; spiral lirae cut the folds into indistinct granules and on the base form coarse granules; aperture small, oblique; columellar callus spread over the umbilical region, and excavate, the outer rim forming a tubercle; operculum spirally ribbed, having a granular surface. Genotype, *Trochus aureus* Jonas, 1844.

The genotype has been recorded from numerous places in the Flindersian Region, and has been located in various genera. Pilsbry places it in *Cyclocantha* Swainson, remarking, "A very attractive little species, quite distinct from its nearest allies." Swainson records it as *Carinidea granulata,* and Tenison-Woods as *Carinidea tasmanica* in 1877 and *Carinidea ornata* in 1876. *Carinidea* does not appear to have any relationship to the present species and Pilsbry has remarked on its distinctions from other species of *Cyclocantha.* The above genus is therefore introduced.

MICRASTRAEA AUREA (Jonas, 1844).

Trochus aureus Jonas, Zeits, Malak., 1844, p. 168.

Loc. 1, 2, 3.

MICRASTRAEA RUTIDOLOMA (Tate, 1893).

Turbo (Astralium) rutidoloma Tate, Tr. R. Soc. S. Aust., 1893, p. 192.

Loc. 1.

Family EUTROPIIDAE.

PHASIANELLA AUSTRALIS (Gmelin, 1788).

Buccinum australe Gmel., Syst. Nat., 1788, p. 3490, No. 173.

Loc. 1; common.

PHASIANELLA, VENTRICOSA Swainson, 1822.

Phasianella ventricosa Swainson, Cat. Coll. Shells Bligh, 1822, P. 15.

Loc. 1; common.

Family NERITIDAE.

NERITA (MELANERITA) MELANOTRAGUS Smith, 1884.

Nerita melanotragus Smith, Zool. Alert., 1884, p. 69.

Loc. 1, 2, 3, 4, 5, 6, 7; common on reefs.

Family LITTORINIDAE.

MELARHAPHE UNIFASCIATA (Gray, 1826).

Littorina unifasciata Gray, King's Survey Aust., Append., II, 1826, p. 483.

Melarhaphe mauritiana Reeve, Conch. Icon., X., 1857, pl. 17, f. 100.

Loc. 3; common on gneissic rocks.

Family HIPPONICIDAE.

SABIA (SABIA) CONICA (Schumacher, 1817).

Amalthea conica Schum., Essai, 1817, p. 81, pl. 21, f. 4.

Loc. 1, 2, 3, 4.

SABIA (ANTISABIA) FOLIACEA (Quoy and Gaimard, 1835).

Hipponix foliacea Q. and G., Zool. de l'Astrolabe, III., 1835, p. 434, pl. 72, f. 41-45.

Loc. 1, 3, 4; in shell sand.

SABIA (ANTISABIA) ERMA sp. nov.

(Pl. vii., fig. 8.)

Shell conical, thick concentrically distantly frilled; frills numbering sixteen, smooth except for microscopic, obsolete, interrupted short radials; protoconch smooth, conical, set in the middle of the first frill pointing laterally and overhanging the base.

Holotype, height 9 mm., width 19 mm.; Reevsby Island (Reg. No. D.13306, S.A. Musuem).

This species has been taken at various places between Yorke Peninsula, S. Aust., and Rottnest, W.A. In South Australia it has been confused with *foliacea* and in Western Australia with *antiquata* Linne, a South American species.

Family CAPULIDAE.

CAPULUS BANKSI sp. nov.

(Pl. vii., fig. 7.)

Shell large, conical, and thin; sculpture of numerous, fine, regular concentrics formed by the edges of very weak concentric frills which are not prominent; the frills are sculptured by microscopic numerous, packed short radials; protoconch spiral, small, overhanging the base of the shell; base regular, ovate; a fine periostracum covers the shell and bristles from it project from the edges of the concentric lamellae.

Holotype, height 11 mm., width 21 mm.; Reevesby Island, shallow water. (Reg. No. D.13307, S.A. Museum.)

One specimen only was taken but there is another in the S. Aust. Museum taken by Dr. Torr at Neptune Island.

Family CERITHIIDAE.

BITTIUM (BATILLARIELLA) ESTUARINUM Tate, 1893.

Bittium estuarinum Tate, Tr. R. Soc. S. Aust., XVII., 1893, p. 190, pl. 1, f. 12.

Loc. 1; dead specimens in sands at 2 feet, but no living examples. The South Australian Museum has numerous specimens from Yalata Station, 30 miles north of Fowlers Bay, taken at 1 foot beneath land surface by Mrs. D. Bates.

BITTIUM (EUBITTIUM) LAWLEYANUM Crosse, 1863.

Bittium lawleyanum Crosse, Journ. de Conch., XI., 1863, p. 87., pl. 1, fig. 4.

Loc. 1; living on weeds in shallow water.

Family SCALIDAE.

Iredale has elevated Boury's subgenera of this family to generic rank and has added a few extra genera; some may prove, on further study, to be synonyms of Boury's earlier subgenera For this reason all are here treated as subgenera.

SCALA (LAEVISCALA) GODFREYI sp. nov.

(Pl. vii., fig. 3.)

Shell elongate, whorls ten, thin, varices thin, well spaced, rolled back, continuous, numbering seven on the body whorl; interstices very finely irregularly, obsoletely spirally striate, and more finely longitudinally striate; mouth oval, lips complete; basal rib narrow.

Holotype, length 23 mm., breadth 8 mm.; Reevesby Island (Reg. No. D.13305, S.A. Museum). This holotype is an average sized specimen.

The species has been misnamed *aculeata* Sowerby, from Hong Kong. The nearest described species is *tacita* Iredale, from Sydney Harbour. The present species differs in having much less regular and less marked interstitial sculpture, resembling rather that of *minora* Iredale.

SCALA (PLASTISCALA) VERCONIS sp. nov.

(Pl. vii., fig. 5.)

Shell small, weakly sculptured, with low fairly sharp longitudinal ribs crossed by concentric lirae; adult whorls seven, protoconch of one and a half, smooth, mamillate whorls; imperforate; aperture subrotund, about twenty-four longitudinal ribs on the body whorl are crossed by numerous spiral lirae, basal cord very indistinct.

Holotype, length 8 mm., breadth 2.3 mm.; Reevesby Island, in shell sand (Reg. No. D.13300, S.A. Museum).

This species is related to the Peronian *morchi* Angas but differs in the greater validity of the sculpture and general appearance. In the Peronian Region we find *morchi* and the deeper water subspecies *bentha* and *profundior*. In the Flindersian Region we have *verconis* and the deeper water *invalida*, but the latter is so distinct in sculpture that it is retained as a full species.

SCALA (POMISCALA) REEVESBYI sp. nov.

(Pl. vii., fig. 1.)

Shell medium size, apical angle wide; imperforate; whorls six, sculptured with longitudinal lamellae continuous from whorl to whorl; interspaces smooth, faint basal cord present; protoconch of one and a half, smooth, depressed whorls; twelve longitudinal lamellae on the last whorl.

Holotype, length 26 mm., breadth 12 mm.; Reevesby Island (Reg. No. D.13299, S.A. Museum).

One specimen only was taken. This species can be distinguished on sight from the Peronian *perplicata* Iredale by the much more slender form and less developed basal rib.

Family CYMATIIDAE.

NEGYRINA SUBDISTORTA (Lamarck 1822).

Triton subdistortum Lamk., Anim. S. Vert., VII., 1822, p. 186.

Loc. 1; one typical, the others are a more slender finer sculptured rounded-whorl form commonly found in South Australia. A series proves that they are variants of one species.

Family CASSIDIDAE.

HYPOCASSIS FIMBRIATA (Quoy and Gaimard, 1833).

Cassis fimbriata Q. and G., Zool de l'Astrolabe II., 1833, p. 569, pl. 43, f. 78.

Loc. 1, 3; one small and two large specimens, the former resembling the subspecies, *decresensis* Hedley.

Family CYPRAEIDAE.

ZOILA THERSITES (Gaskoin, 1848).

Cypraea thersites Gask., P.Z.S., 1848, p. 90.

Loc. 1; six specimens. Common, alive, off west coast of Reevesby Island, at about 2 fathoms.

NOTOCYPRAEA VERCONIS Cotton and Godfrey, 1932.

Notocypraea verconis C. and G., S. Aust. Nat., XIII., 1932, p. 41, pl. 1, f. 8.

Loc. 1, 2, 3, 4.

AUSTROCYPRAEA REEVEI (Sowerby, 1832).

Cypraea reevei Sow., Conch. Illus., 1832, pl. 8, f. 52.

Loc. 1; one specimen.

Family VOLUTIDAE.

AMORENA UNDULATA (Lamarck, 1804).

Voluta undulata Lamk., Ann. Mag. Nat. Hist., V., 1804, p. 157, pl. 12, f. 1.

Loc. 1; numerous.

ERICUSA FULGETRUM (Sowerby, 1825).

Voluta fulgetrum Sow., Tank. Cat., 1825, pls. 4, 5.

Loc. 1, 3, 4; one living specimen approaches the variety *dictua* Verco.

Lyria multicostata (Broderip, 1827).

Voluta multicostata Brod., Zool. Journ., III., 1827, p. 82, pl. 3, f. 2.

Loc. 1; numerous.

Family CONIDAE.

Floraconus anemone (Lamarck, 1810).

Conus anemone Lamk., Ann. du Mus., XV., 1810, p. 272.

Loc. 1, 2, 3, 4; common, varying from medium to long spires.

Parviconus rutilus (Menke, 1843).

Conus rutilus Menke, Moll. Nov. Holl., 1843, p. 27.

Loc. 1; three specimens.

Family BUCCINIDAE.

Cominella lineolata (Lamarck, 1822).

Buccinum lineolatum Lamk., Anim. S. Vert., VII., 1822, p. 267.

Loc. 1, 2, 3, 4, 5; numerous.

Family NASSARIIDAE.

Reticunassa paupera (Gould, 1850).

Nassa paupera Gould, Pr. Boston Nat. Hist. Soc., III., 1850, p. 155

Loc. 2; in shell sand; very variable.

Niotha pyrrhus (Menke, 1843).

Buccinum pyrrhum Menke, Moll, Nov. Holl., 1843, p. 21.

Alectrion victorianus Ird., Tr. N.Z. Inst., 1915, p. 467.

Loc. 2; numerous on tidal sand flats.

Parcanassa pauperata (Lamarch, 1822).

Buccinum pauperatum Lamk., Anim. S. Vert., VII., 1822, p. 278.

Loc. 2; numerous on tidal sand flats.

Nassarius particeps (Hedley, 1915).

Arcularia particeps Hedley, Pr. Linn. Soc. N.S.W., XXXIX., 1915, p. 738.

Loc. 1; two shells.

Family PYRENIDAE.

Zemitrella nux (Reeve, 1859).

Columbella nux Reeve, Conch. Icon., XI., pl. XXXV., f. 227, 1859.

Loc. 1; two specimens.

The specimens have been allotted to Reeve's species *nux*, type locality Port Adelaide, in prefence to Gaskoin's species *pulla*, described without type locality but allowed by previous authors in the South Australian list. The two specimens agree fairly well with Reeve's figure.

ZEMITRELLA ACUMINATA (Menke, 1843).

Buccinum acuminatum Menke, Moll. Nov. Holl., 1843, p. 20.

Loc. 1; numerous.

ZEMITRELLA PURPUREOCINCTA (Verco, 1910).

Pyrene menkeana purpureocincta Verco, Tr. R. Soc. S. Aust., XXXIV., 1910, p. 347.

Loc. 1; one specimen.

Family MURICIDAE.

PTERONOTUS TRIFORMIS (Reeve, 1845).

Murex triformis Reeve, Conch. Icon., III., 1845, pl. 13, f. 53.

Loc. 1, 2, 3.

Family THAIDIDAE.

NEOTHAIS TEXTILIOSA (Lamarck, 1822).

Purpura textiliosa Lamk., Anim. S. Vert., VII., 1822, p. 77.

Loc. 2, 3; six specimens; one large shell contained a hermit crab, *Paguristes frontalis* Milne Edwards.

Family LAOMIDAE.

PARALAOMA STABILIS (Iredale, 1937).

Helix arenicola Tate, Pr. Linn. Soc. N.S.W., II., 1878, p. 291.

Paralaoma stabilis Ird., S. Aust. Nat., XVIII., 2, 1937, p. 20.

Reevesby Island; numerous examples taken by J. Clark and the author.

MISELAOMA REEVESBYI sp. nov.

(Pl. vii., fig. 4.)

Shell small, fragile, horn coloured, sinistral, very narrowly umbilicated, spire elevated, protoconch depressed; whorls including protoconch four and a half, flatly rounded; subangulate, sutures impressed; sculpture of axial fine striae on the adult whorls; protoconch microscopically interruptedly spirally lirate.

Holotype, height 1.4 mm., breadth 1.5 mm.; Reevesby Island (Reg. No. D.13296, S.A. Museum).

Three specimens in all have been picked out from the numerous small shells taken on the Island. At first this species was thought to be the immature tip of *Omegapilla australis*. The subangulate whorls, large size and different shape, distinguish this species from the Victorian *Laoma sinistra* Gabriel.

Family SUCCINEIDAE.

SUCCINEA (AUSTROSUCCINEA) AUSTRALIS (Ferussac, 1821).

Helix australis Ferussac, Tabl. Syst. Limacons, pt. 2, 1821, p. 31, pl. XI., fig. 11.

Reevesby Island; numerous.

SUCCINEA (ARBORCINEA) ARBOREA Angas, 1864.

Succinea arborea Angas, P.Z.S., 1864, p. 523.

Reevesby Island; under bark of *Myoporum insularae.*

Family VERTIGINIDAE.

THEMAPUPA ADELAIDAE (Angas, 1864).

Buliminus (Chondrula) adelaidae Angas, P.Z.S., 1863, p. 522.

Reevesby Island; three specimens.

OMEGAPILLA AUSTRALIS (Angas, 1864).

Vertigo australis Angas, P.Z.S., 1863, p. 522.

Reevesby Island; numerous.

AUSTRALBINULA MARGARETAE (Cox, 1868).

Pupa margaretae Cox, Mon. Aust. Land Shells, 1868, p. 80, pl. XIV., f. 20*a*.

Reevesby Island; numerous.

Family CHAROPIDAE.

DISCOCHAROPA INSULARIS sp. nov.

(Pl. vii., fig. 6.)

Shell small, thin, flattened, horn coloured; whorls three, sculptured with distant, radial ribs, the interstices filled with much finer accremental striae; protoconch large, smooth, of one and a half whorls; umbilicus wide, mouth simple.

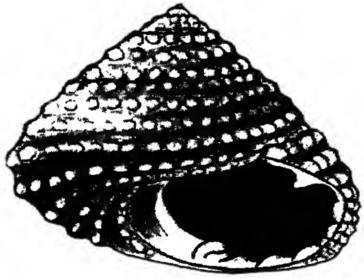
Holotype, height 1 mm., breadth 2 mm.; Reevesby Island (Reg. No. D.13297, S.A. Museum).

Reevesby Island; four specimens. Readily separable from the Central Australian *planorbulina* Tate.

Explanation of Plate.

1. **Scala (Pomiscala) reevesbyi sp. nov.** × 2.
2. **Clanculus (Isoclanculus) weedingi sp. nov.** × 4.
3. **Scala (Laeviscala) godfreyi sp. nov.** × 2.
4. **Miselaoma reevesbyi sp. nov.** × 28.
5. **Scala (Plastiscala) verconis sp. nov.** × 3. 6.
6. **Discocharopa insularis sp. nov.** × 22.
7. **Capulus banksi sp. nov.** × 2.4.
8. **Sabia (Antisabia) erma sp. nov.** × 3.

1



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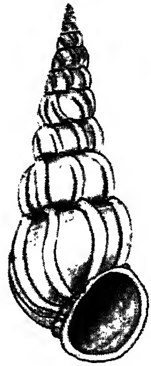

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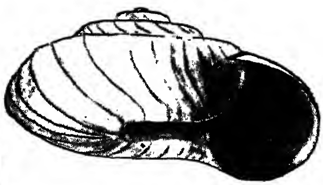

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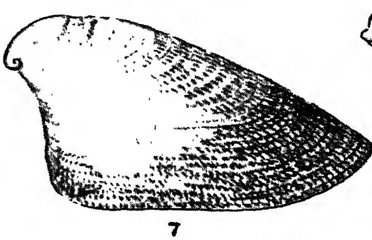

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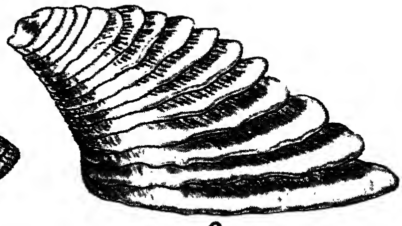

8

5. *Pisces.*

By J. S. GUEST and D. B. ROBERTSON.

Methods adopted for procuring specimens were:—

(*a*) Rock pools were poisoned with chloride of lime or hand nets used.

(*b*) A 75 fathom seine net was used extensively at Home Bay, the only situation suitable for netting on Reevesby Island.

(*c*) Hand lines were used, mainly in water up to 6 fathoms.

(*d*) Dredging was carried out mainly off the west and south coasts of Reevesby Island.

Although the most detailed study was made at Reevesby Island and most of the species were obtained at or near that island, a less detailed survey of the rest of the group indicated that most of the Reevesby fish were common throughout.

As well as fish of economic importance such as Whiting (*Sillaginodes punctatus*), Sweep (*Scorpis georgianus*) and Schnapper (*Pagrosomus auratus*) which were extensively caught by local fishermen, many other excellent edible fish were obtained, such as Trevally (*Caranx georgianus*), Garfish (*Hyporhamphus intermedius*), and Flathead (*Platycephalus bassensis*). Poorer types of fish such as Australian Salmon, Parrot Fish, and Leather Jackets were present in enormous numbers, while the commonest inhabitants of rock pools were the Jumping Blenny and Zebra Fishes.

The nomenclature adopted in this report (except in the case of *Spheroides pleurogramma*) is that used by Waite in the Catalogue of the Fishes of South Australia (Rec. S.A. Mus., ii., 1921-24, pp. 1-208) and in "The Fishes of South Australia" (Brit. Sci. Guild Handbook, Adelaide, 1923). Only the most significant references to synonymy are given.

Sub-class ELASMOBRANCHII.

Order SELACHII.

Family HETERODONTIDAE.

HETERODONTUS PHILIPPI (Bloch and Schneider, 1801). (Port Jackson Shark.)

Squalus philippi Bl. and Schn., Syst. Ichth., 1801, p. 134.

Heterodontus philippi (Bl. and Schn.). Blainville, Bull. Soc. Phil., 1816, p. 121.

Several egg cases of this species were found on the beaches of Reevesby Island.

Order BATOIDEI.

Family RHINOBATIDAE.

TRIGONORRHINA FASCIATA (Müller and Henle, 1837). (Fiddler).

Trigonorrhina fasciata Müller and Henle, Mag. Nat. Hist., (2), ii., 1837, p. 90, and Plagiost; 1838, p. 124, pl. xlii.

Family MYLIOBATIDAE.

MYLIOBATIS TENUICAUDATUS (Hector, 1877). (Eagle Ray.)

Myliobatis tenuicaudatus Hector, T.N.Z. Inst., ix., 1877, p. 468.

Very commonly seen in shallow water.

Sub-class TELEOSTOMI.

Order ISOSPONDYLI.

Family CLUPEIDAE.

STOLEPHORUS ROBUSTUS (Ogilby, 1898). (Blue Sprat.)

Spratelloides robustus Ogilby, P.L.S. N.S.W., xxii., 1898, p. 64.
Stolephorus robustus (Ogilby), Waite, Mem. N.S.W. Nat. Club, ii., 1904, p. 12.

Family GONORHYNCHIDAE.

GONORHYNCHUS GREYI (Richardson, 1845). (Sand Fish.)

Rhynchana greyi Rich., Zool. Erebus and Terror, 1845, p. 44, pl. xxix., figs. i-vi and text fig.
Gonorhynchus greyi (Rich.), Gunther, Cat. Fish. Brit. Mus., vii., 1868, p. 373.

One specimen, 33 cm. in length, was taken.

Order NEMATOGNATHI.

Family PLOTOSIDAE.

CNIDOGLANIS MEGASTOMA (Richardson, 1845). (Estuary Catfish.)

Plotosus megastomus Rich., *loc. cit.*, 1845, p. 31, pl. xxi., figs. i-iii.
Cnidoglanis megastoma (Rich.), Gunther, Cat. Fish. Brit. Mus., v., 1864, p. 27.

Order SYMBRANCHII.

Family SYMBRANCHIDAE.

CHEILOBRANCHUS RUFUS (Macleay, 1881). (Shore Eel.)

Cheilobranchus rufus Macleay, P.L.S., N.S.W., vi., 1881, p. 266.

Found in numbers in almost every rock pool examined throughout the group.

Order SOLENICHTHYES.

Family SYNGNATHIDAE.

LISSOCAMPUS CAUDALIS (Waite and Hale, 1921). (Smooth Pipefish.)

Lissocampus caudalis Waite and Hale, Rec. S.A. Mus., i., 1921, p. 306, fig. xlvi.

Order SYNENTOGNATHI.

Family HEMIRHAMPHIDAE.

HYPORHAMPHUS INTERMEDIUS (Cantor, 1842). (Garfish.)

Hemirhamphus intermedius Cantor, A.M.N.H., ix., 1842, p. 485.

Hyporhamphus intermedius (Cant.), Waite, Rec. S.A. Mus., ii., 1921, p. 65, fig. 98.

Commonly netted in Home Bay.

Order PERCOMORPHI.

Sub-order PERCESOCES.

Family ATHERINIDAE.

ATHERINA MICROSTOMA (Gunther, 1861). (Large-scaled Atherine.)

Atherina microstoma Gunth., Cat. Fish. Brit. Mus., iii., 1861, p. 401.

Family MUGILIDAE.

AGONOSTOMUS FORSTERI (Bloch and Schneider, 1801). (Freshwater Mullet, Conmuri.)

Albula forsteri Bl. and Schn., *loc. cit.*, 1801, pp. xxxii and 120.

Agonostoma forsteri (Bl. and Schn.), Gunther, *loc. cit.*, 1861, p. 465.

Only juvenile specimens taken.

Family SPHYRAENIDAE.

SPHYRAENA NOVAE-HOLLANDIAE (Gunther, 1860). (Snook, Short-finned Pike.)

Sphyraena novae-hollandiae Gunth., Cat. Fish. Brit. Mus., ii., 1860, p. 335.

Netted at Home Bay.

Sub-order PERCOIDEA.

Division PERCIFORMES.

Family SILLAGINIDAE.

SILLAGINODES PUNCTATUS (Cuvier and Valenciennes, 1829). (Spotted Whiting.)

Sillago punctata Cuv. and Val., Hist. Nat. Poiss., iii., 1829A, p. 413.

Sillaginodes punctatus (Cuv. and Val.), Gill, Proc. Acad. Nat. Sci. Phil., 1861, p. 505.

Commonly caught on handlines in 3-4 fathoms.

Family CARANGIDAE.

CARANX GEORGIANUS (Cuvier and Valenciennes, 1833). (Trevally.)

Caranx georgianus Cuv. and Val., Hist. Nat. Poiss., ix., 1833, p. 85.

Caught in large numbers at Reevesby and Little English Islands.

SERIOLA GRANDIS (Castelnau, 1872). (Yellowtail.)

Seriola grandis Castelnau, P.Z.S. Vic., i., 1872, p. 115.

Family ARRIPIDIDAE.

ARRIPIS TRUTTA (Forster, 1801). (Australian Salmon.)

Sciaena trutta Forster, in Bloch and Schneider, *loc. cit.*, 1801, p. 542.

Arripis trutta (Forster), Gill, Mem. Nat. Acad. Sci., vi., 1893, p. 116.

Enormous shoals seen in shallow water throughout the group.

ARRIPIS GEORGIANUS (Cuvier and Valenciennes, 1831). (Tommy Rough, Wankaldi.)

Centropristes georgianus Cuv. and Val., Hist. Nat. Poiss., vii., 1831, p. 451.

Arripis georgianus (Cuv. and Val.), Jenyns, Voy. Beagle, 1842, p. 14.

Very common.

Family SCIAENIDAE.

SCIAENA ANTARCTICA (Castelnau, 1872). (Butterfish, Mulloway.)

Sciaena antarctica Castelnau, *loc. cit.*, 1872, p. 100.

Noted in clear water off Roxby Island.

Family MULLIDAE.

UPENEUS POROSUS (Cuvier and Valenciennes, 1829). (Red Mullet.)

Upeneus porosus Cuv. and Val., *loc. cit.*, 1829A, p. 455.

One specimen taken.

Family SPARIDAE.

PAGROSOMUS AURATUS (Forster, 1801). (Schnapper.)

Sciaena aurata Forster, in Bloch and Schneider, *loc. cit.*, 1801, p. 266.

Pagrosomus auratus (Forster), Gill, *loc. cit.*, 1893, pp. 97, 116, 123.

Common; schnapper grounds west of Roxby used by fishermen.

Family SCORPIDIDAE.

SCORPIS GEORGIANUS (Cuvier and Valenciennes, 1831). (Banded Sweep.)

Scorpis georgianus Cuv. and Val., Hist. Nat. Poiss, viii., 1831, p. 503, pl. ccxlv.

Caught in large numbers on hand lines.

Family GIRELLIDAE.

MELAMBAPHES ZEBRA (Richardson, 1846). (Zebra Fish.)

Crenidens zebra Rich., Zool. Ereb. Terr., 1846, p. 70.
Tephraeops zebra (Rich.), Gunther, Cat. Fish. Brit. Mus., i., 1859, p. 432.

Melambaphes zebra (Rich.), Waite, Fishes S. Aust., 1923, p. 137.

Very common in all rock pools examined.

Family ENOPLOSIDAE.

ENOPLOSUS ARMATUS (Shaw, 1790). (Old Wife.)

Chaetodon armatus Shaw, in White's Voy. N.S.W., 1790, p. 254, pl. xxxix., fig. i.

Enoplosus armatus (Shaw), Cuv. and Val., Hist. Nat. Poiss., ii., 1828, p. 133, pl. xx.

Division CIRRHITIFORMES.

Family CHEILODACTYLIDAE.

GONIISTIUS VIZONARIUS (Kent, 1887). (Magpie Perch.)

Cheilodactylus gibbosus Castelnau, *loc. cit.*, 1872, p. 75 (not Rich.).
Chilodactylus vizonarius Kent, P.R.S. Tas., 1887. p. xxx, 48.
Goniistius vizonarius (Kent), McCulloch, Endeavor Res., i., 1911, p. 64, pl. xi.

Division LABRIFORMES.

Family LABRIDAE.

Members of this family (Parrot Fishes) were extremely common on weedy and rocky bottoms.

PSEUDOLABRUS PSITTACULUS (Richardson, 1840). (Rosy Parrot Fish.)

Labrus psittaculus Rich., P.Z.S., 1840, p. 26 and Zool. Ereb. Terr, 1848, p. 129, pl. lvi., figs. vii-x.

Pseudolabrus psittaculus (Rich.), McCulloch, *loc. cit.*, 1911, p. 77, fig. xix.

PSEUDOLABRUS FUCICOLA (Richardson, 1840). (Purple Parrot Fish.)

Labrus fucicola Rich., *loc. cit.*, 1840, p. 26 and *loc. cit.*, 1848, p. 127, pl. liv., figs. i., ii.

Pseudolabrus fucicola (Rich.), Gill, *loc. cit.*, 1893, p. 116.

PSEUDOLABRUS CELIDOTUS (Forster, 1801). (Spotty.)

Labrus celidotus Forster, in Bloch and Schneider, *loc. cit.*, 1801, p. 265.

Pseudolabrus celidotus (Forster), Gill, *loc. cit.*, 1893, pp. 98, 117.

PSEUDOLABRUS TETRICUS (Richardson, 1840). (Blue-throated Parrot Fish.)

Labrus tetricus Rich., *loc. cit.*, 1840, p. 25 and *loc. cit.*, 1848, p. 126, pl. lv., figs. i.-iv.

Pseudolabrus tetricus (Rich), Waite, *loc. cit.*, 1921, p. 130.

PSEUDOLABRUS PUNCTULATUS (Gunther, 1862). (Blue-spotted Parrot Fish.)

Labrichthys punctulata Gunther, Cat. Fish. Brit. Mus., iv., 1862, p. 118.

Pseudolabrus punctulatus (Gunth.), Gill, P.U.S. Nat. Mus., xiv., 1892, p. 401.

PICTILABRUS LATICLAVIUS (Richardson, 1839). (Senator Fish.)

Labrus laticlavius Rich., P.Z.S., 1839, p. 99 and *loc. cit.*, 1848, p. 128, pl. lvi., figs. iii.-vi.

Pictilabrus laticlavius (Rich.), Gill, *loc. cit.*, 1892, p. 403.

Family ODACIDAE.

ODAX sp.

Sub-order GOBIOIDEA.

Family GOBIIDAE.

GOBIUS HINSBYI (McCulloch and Ogilby, 1919). (Girded Goby.)

Gobius pictus Castelnau, *loc. cit.*, 1872, p. 124 (not Malm.).

Gobius hinsbyi Johnston, P.R.S. Tas., 1903, p. x. (name only); *idem*, McCulloch and Ogilby, Rec. Aust. Mus., xii., 1919, p. 215, pl. xxxiii., fig. i.

Dredged between Reevesby and Partney Islands.

GOBIUS LATERALIS (Macleay, 1881). (Spotted Goby.)

Gobius lateralis Macleay, P.L.S. N.S.W., v., 1881, p. 602.

Sub-order BLENNIOIDEA.

Family BLENNIIDAE.

BLENNIUS TASMANIANUS (Richardson, 1839). (Blenny.)

Blennius tasmanianus Rich., *loc. cit.*, 1839, p. 99; *idem*, T.Z.S., iii., 1849, p. 129.

Frequently found in rock pools.

OPHICLINUS GRACILIS (Waite, 1906). (Black-backed Snake Blenny.)

Ophiclinus gracilis Waite, Rec. Aust. Mus., vi., 1906, p. 207, pl. xxxvi., fig. vi.

One specimen from Kirkby Island.

CRISTICEPS AUSTRALIS (Cuvier and Valenciennes, 1836). (Weed Fish.)

Cristiceps australis Cuv. and Val., Hist. Nat. Poiss., xi., 1836, p. 402, pl. cccxxxvi.

CLINUS PERSPICILLATUS (Cuvier and Valenciennes, 1836). (Eyed Blenny.)

Clinus perspicillatus Cuv. and Val., *loc. cit.*, 1836, p. 372.

LEPIDOBLENNIUS MARMORATUS (Macleay, 1878). (Jumping Blenny.)

Tripterygium marmoratum Macleay, P.L.S. N.S.W., iii., 1878, p. 34, pl. iii., fig. ii.

Lepidoblennius marmoratus (Macleay), McCulloch and McNeill, Rec. Aust. Mus., xii., 1918, p. 24.

One of the most common species occurring in rock pools.

Order HETEROSOMATA.

Family PLEURONECTIDAE.

AMMOTRETIS TUDORI (McCulloch, 1914). (Bass Flounder.)

Ammotretis tudori McCulloch, Endeavor Res., ii., 1914, p. 124, pl. xxvi.

Order SCLEROPAREI.

Family SCORPAENIDAE.

NEOSEBASTES PANDUS (Richardson, 1842). (Gurnard Perch.)

Scorpaena panda Rich., A.M.N.H., ix., 1842, p. 216.

Neosebastes panda (Rich.), Guichenot, Mem. Soc. Sci. Cherbourg, xiii., 1867, p. (86?).

GYMNAPISTES MARMORATUS (Cuvier and Valenciennes, 1829). (Cobbler.)

Apistus marmoratus Cuv. and Val., Hist. Nat. Poiss., iv., 1829, *b*, p. 416.

Gymnapistes marmoratus (Cuv. and Val.), Swainson, Nat. Hist. Fish., ii., 1839, p. 266.

Family PLATYCEPHALIDAE.

PLATYCEPHALUS BASSENSIS (Cuvier and Valenciennes, 1829). (Sand Flathead.)

Platycephalus bassensis (Cuv. and Val., *loc. cit.*, 1829, *b*, p. 247.

Order PLECTOGNATHI.

Division SCLERODERMI.

Family MONACANTHIDAE.

The following members of this family were very common:—

CANTHERINES AYRAUDI (Quoy and Gaimard, 1824). (Yellow Leather Jacket.)

Balistes ayraud Q. and G., Voy, Uran. et Physic., 1824, p. 216, pl. xlvii., fig. ii.

Cantherines ayraudi (Q. and G.), Waite, *loc. cit.*, 1921, p. 186.

CANTHERINES SETOSUS (Waite, 1899). (Velvet Leather Jacket.)

Monacanthus setosus Waite, Mem. Aust. Mus., iv., 1899, p. 91, pl. xvi.

Cantherines setosus (Waite), Waite and McCulloch, T.R.S.S. Aust., xxxix., 1915, p. 472, pl. xiv.

CANTHERINES MOSAICUS (Ramsay and Ogilby, 1886). (Mosaic Leather Jacket.)

Monacanthus mosaicus Rams. and Ogil., P.L.S. N.S.W. (2), i., 1886, p. 5.

Cantherines mosaicus (Rams. and Ogil.), McCulloch, Endeavor Res., iii., 1915, p. 170, pl. xxxvii., figs. i., ii.

Family OSTRACIONTIDAE.

ARACANA ORNATA (Gray, 1838). (Common Cowfish.)

Aracana ornata Gray, A.M.N.H., i., 1838, p. 110.

ARACANA FLAVIGASTRA (Gray, 1838). (Yellow-bellied Cowfish.)

Aracana flavigastra Gray, *loc. cit.*, 1838, p. 110.

Division GYMNODONTES.

Family TETRADONTIDAE.

SPHEROIDES PLEUOGRAMMA (Regan, 1902). (Common Toado.)

Tetrodon pleurogramma Regan, P.Z.S., 1902, p. 300, pl. xxiv., fig. ii.

Spheroides pleurogramma (Regan), McCulloch, Rec. W.A. Mus., i., 1914, p. 227; *idem*, Waite, Rec. S.A. Mus., ii., 1924, p. 486, pl. xxx., fig. ii.

Spheroides lacrimosus Waite, *loc. cit.*, 1923, p. 226.

TETRAODON ARMILLA (Waite and McCulloch, 1915). (Ringed Toado.)

Tetraodon armilla Waite and McCulloch, *loc. cit.*, 1915, p. 475, pl. xv.

H. J. GREEN, Government Printer, Melbourne.

[Proc. Roy. Soc. Victoria, 51 (N.S.), Pt. II., 1939.]

Art. IX.—*The Problem of Hard Seeds in Subterranean Clover.*

By YVONNE AITKEN, M.Agr.Sc.

[Read 13th October, 1938; issued separately, 24th July, 1939.]

Introduction.

It has long been known that a seed, though viable, may be unable to germinate under favourable conditions, through either dormancy of the embryo, or an impermeable seedcoat. A seed in which impermeability of the seedcoat prevents water absorption, is termed "hard", whereas a permeable seed is "soft". "Hardseededness" occurs characteristically in the Family Leguminosae and the hard seeds are capable of germination after any treatment which makes the testa pervious, such as cutting by contact with the rough sides of a threshing drum, scratching with sandpaper, slight charring with concentrated sulphuric acid or hot ashes, contact with boiling water. Softening by means of mechanical treatment is important in the commercial harvesting of leguminous crops such as clovers and lucerne. Natural softening in field and store is of significance in the practical value of the species concerned.

The literature on hardseededness has been reviewed by Witte (10). Since 1932, Helgeson (6), Hamly (4), Stevenson (9), and Dutt (3) have contributed valuable information. However, a thorough investigation is still needed over the whole problem of hard seeds in Legumes, in order to understand the sequence of events from the production of a hard seed to its ultimate softening.

Subterranean clover was selected for study on this plan, as a contribution towards such a survey; not only was its formation of hard seeds of economic significance, in its position of the most important annual legume in Australia, but it had the unique characteristic among clovers of burying its seed, and the relation of seed-burial to hardseededness was not known.

The habit of the Subterranean clover plant, its type of flowering, the tendency to bury the flower cluster after fertilization, and the formation of a burr round each group of three or four seeds, are shown in plate XI.

Observations and experiments were made on all available material, including burr of Mt. Barker variety from a commercial grower, commercial samples of seed, and hand-cleaned seed from the strains grown at Burnley Gardens. These were grouped as Early maturing—Dwalganup, Mulwala, Dalliak, Springhurst, and Bacchus Marsh; Midseason—Mt. Barker, White Seed, Mansfield, Nangeela, and Burnerang; and Late maturing—Berlin, Merino, Macarthur, Tallarook, Wenigup, and Bass.

The extent of hardseededness in this clover is indicated by two facts, (1) that each burr usually contains both soft and hard seeds; (2) that in 1937, the percentage of hard seeds varied from 50 per cent. to 95 per cent. in the numerous samples examined less than a month after the burrs of the latest strains had dried—results similar to those of Meadley (7), in the district of Boyup, Western Australia.

Formation of Hard Seeds.

(1) *Relation of Hardness to Seed Development.*

In a normal spring, about one month elapses between fertilization and the growth of the young seed to its maximum size. The seed then dries, and becomes mature.

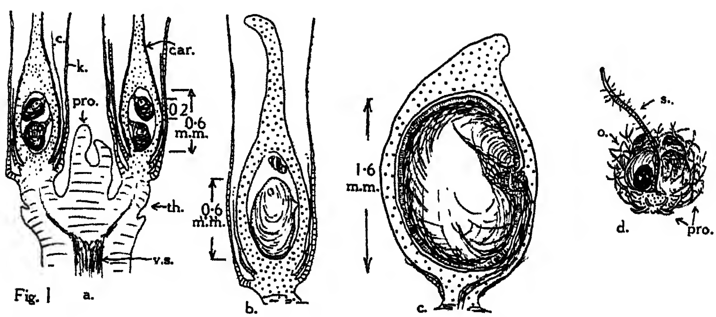

Fig. 1.—Longitudinal sections of the developing ovule of *Trifolium subterraneum;* (*a*) through the florets in a panicle at fertilization, showing two ovules in each ovary; (*b*) through an ovary some days after, showing growth of one ovule only; (*c*) a seed several weeks old, half grown; (*d*) diagram of a mature burr, showing the rosette of infertile calyces round the pods, and a pod opened to show the dried seed within. (v.s. = vascular strand, th. = thalamus, k. = calyx, pro. = primary infertile flowers, c. = petals, car. = carpel, o. = pod, with dried seed exposed, s. = stalk of burr.)

The ovary at fertilization is about 1 mm. long and usually encloses two ovules each about 0.2 mm. long and 0.15 mm. wide (fig. 1*a*). As a rule only one of these ovules develops in each ovary (figs. 1*b*-*d*). When the seed is about 2 mm. long, it is tightly enclosed by the greenish white membraneous ovary wall.

At this stage the testa is colourless. A faint pink soon appears round the hilum and spreads over the seed. The full-sized seed is dark crimson except at the strophiolar and micropylar regions which are paler, and at the hilum which is white owing to the disc of loose cells connecting it to the vascular strand of the ovary. The normal process of drying results in a reduction in the diameter of the seed from about 4 mm. to about 2 mm. and a change in its colour from crimson to purple-black except round the hilum which remains somewhat lighter.

Changes in the permeability of the developing seed were tested by using 1 per cent. osmic acid. The testas of young seeds were rapidly permeated by the acid over most of their surfaces. As development proceeded, the permeable areas diminished in extent. In seeds at their maximum size, the staining occurred as patches scattered over the surface (fig. 8*a*). From this it may be assumed that entry of water is possible over most of the testa before the seed dries. If staining occurs at the strophiole, it is a thin line across the centre. After the drying, the matured seed remains permeable, forming an "original" soft seed, or becomes hard, and this hardness is of variable duration. The seeds that soften, gradually raise the total soft seed percentage in the burrs despite the later hardening of some of the original soft seed. Osmic acid stains the soft seeds derived from hard, with a black spot at the end of the seed nearer the hilum (fig. 8*c*), while the original soft seeds are stained at the radicle tip, or in nearby patches (fig. 8*b*).

(2) *Occurrence of Hardness in the Individual Plant.*

It was noticed that, in many panicles, all the florets did not open at the same time, and this was followed by uneven development of the seeds, as evidenced by differing sizes, and by the variation in the time at which they began to colour pink. It was probable that this unevenness was connected with nutritional retardation in the less advanced seeds, and that these seeds would tend to remain soft, or develop a hardness of short duration. To test the idea, cotton was tied round the base of retarded florets, and the seed of each was separated from the rest in the burr, after ripening and drying out. There was an indication that least advanced florets in the panicle gave rise to some of the seed that softened first.

The position of the burr above or below the soil surface affects the size and time of drying of the seeds. Among burrs of the same age, those developed above ground are green and half the size of the buried burrs which are white. They dry out much later than those on the surface, because of the lowered maximum temperatures (Table 1) and more moist conditions. The seeds in the buried burrs are slightly larger, and the number of seeds matured per burr more than in the surface burrs; the increase seems due to the longer time for development before

TABLE 1.

Daily maximum and minimum temperatures in degrees Fahrenheit for air, soil surface, and just below surface, November and December, 1938.

Date.	Air.	Soil Surface.	Date.	½-in. below Surface.	Soil Surface.
Nov. 25 ..	52–74	50–103	Dec. 3 ..	50–116	47–125
„ 26 ..	48–82	46–106	„ 7 ..	56–94	52–100
„ 28 ..	60–94	56–108	„ 19 ..	48–112	46–123
„ 29 ..	52–82	46–108	„ 22 ..	40–110	46–122
			„ 28 ..	–112	–131
Average ..	53–83	49–106			
Variation in Max. Temp., 20° F.			Variation in Max. Temp. 10–20° F.		

drying. That length of development is linked with hardseededness was shown in an experiment with a row of plants of Bacchus Marsh strain. Burrs on one side of the row were encouraged to develop below the soil surface, which was kept moist till about a month after the drying of the burrs on the other side, where they had been prevented from burying. Seeds from the buried burrs, after drying on the plants, proved to be slightly more hardseeded than the surface seeds. Further drying of both types under a very low saturation deficit, caused an increased percentage of hard seeds in the buried burrs, which were evidently of higher potential hardseededness than those formed above ground.

The evidence that the stage of development of the seed at drying was important in determining its subsequent hardness, is supported by the distribution of hard and soft seeds according to the position of burrs along a runner. In plants or burrs collected while green, and allowed to dry, seeds from the younger burrs contained a higher percentage of soft seed than from the older—as shown in Table 2. Burrs from a plant of Dalliak strain were among those analysed in greater detail, and shows the same trend in Table 3.

TABLE 2.

Variation in yield of soft seeds along the runner. Burrs from 1937 harvest, Burnley, tested 10th January, 1938; plants cut in November while green. (Approx. 200 seeds per strain.)

Strain.	Percentage of Soft Seeds in Burrs.	
	Basal (First to Third Burrs).	Upper (Sixth Burr and Higher).
Berlin	14	52
Tallarook	1	15
Madrid	16, 25	42, 40
Dalliak	1	14

TABLE 3.

Typical analysis of a plant harvested green. The occurrence of softness according to burr position is stated.

Position of Burr along Runner.	Soft Seeds.	Total Seeds.	Percentage of Soft Seeds.
			%
Basal 1	18	76	28
2	19	56	
3	17	47	
Mid 4	19	68	
5	9	31	33
6	21	58	
Upper 7	10	40	
8	14	27	40
9	5	22	
10	5	18	
11	7	12	70
12	7	9	

It would be expected from this, that in a range of strains grown together, the advent of hot, dry weather towards the end of the growing season would tend to dry off the youngest seeds of the later stains before they were fully developed. This would cause a characteristically higher percentage of soft seeds than would occur in earlier strains in which the seed had longer time to

TABLE 4.

Variation in soft seed yield a/c strain and position of flower along runner. (Seeds collected from Burnley plots in mid-November and tested at end of month.)

Strain Maturity.	Name.	Soft Seeds.	Total Seeds.	Percentage Soft a/c Position.
				%
Earliest ..	Dwalganup ..	3	51	Basal .. 0
				Mid .. 6
				Upper .. 20
Early	Mulwala ..	15	43	B. .. 16
				M. .. 65
				U. .. 60
Early-mid ..	Springhurst ..	17	83	B. .. 7
				M. .. 25
				U. .. 41
,, ..	Bacchus Marsh	32	117	B. .. 11
				U. .. 42
Mid-season ..	Mt. Barker ..	6	26	B. .. 22
,, ..	White Seed ..	10	41	B. .. 18
				U. .. 57
,, ..	Mansfield ..	35	64	B. .. 55
,, ..	Nangeela ..	22	56	B. .. 40
,, ..	Burnerang ..	46	48	B. .. 96
Late	Merino ..	31	37	B. .. 84
,, ...	Macarthur ..	36	39	B. .. 93
,, ...	Tallarook ..	16	16	B. .. 100

develop. This seems to be borne out by field observations up to date. A late strain (Tallarook), had a relatively high percentage of soft seed, in December 1937, and a heavy germination in the ground after the rains in January 1938. The early strains (Dwalganup, Dalliak, and Mulwala) had few soft seeds, and a very low germination in the plots. The general correlation of softness with lateness of maturity is seen in Table 4, but the variation in results indicates the necessity for further data on the effect of variety on hardseededness, as distinct from its effect on the time of seed development.

The degree of drying of the seed was found to be important in hard seed formation, when burr from the same varieties was gathered at intervals from October to December 1938. Each set was further dried under standard conditions, and then tested. The longer the seeds were allowed to dry out on the plant, the higher the percentage of hard seed (Table 5).

TABLE 5.

Variation in soft seed yield a/c strain and time of harvesting.

Strain.	Percentage Soft Seeds.—Time of Harvesting, Nov.-Dec., 1938.		
	15/11.	23/11.	14/12.
	%	%	%
Bacchus Marsh	40	..	30
Mt. Barker	72	40	..
White Seed	80	..	23
Macarthur	100	53	..
Tallarook	100	51	18

Observations were made on the variation in hardseededness in the plants of a strain row. In each of several strains, twelve individuals were selected out of about 90, and the burrs dried further under standard conditions before testing in December. There was a wide range, due to a few plants having soft seed percentages well away from the mean.

Strains are chiefly distinguished by their differential response to environmental conditions, particularly as to time of flowering. A previous paragraph has indicated the correlation of late strains with less hardseededness, because of the less development of seeds before drying. A further confirmation of the importance of seed development was obtained by causing a number of strains to begin flowering several weeks earlier than usual for the Melbourne district. Earlier flowering resulted from growing the strains at Swan Hill, Cohuna, and Rutherglen. Sufficient watering enabled the flowering plants in the northern districts

to grow until December, and so lengthened the growing period by about three weeks. The flowering period was thus increased by about a month. This resulted in all strains being more hard-seeded than those at Burnley, when sampled at the end of November. The hard seed percentage in plants of the nine strains, grown at Swan Hill and Burnley, are compared in Table 6.

TABLE 6.

Variation in soft seed yield a/c strain and district. Harvested end October, 1938.

Strain.	Percentage Soft Seeds.	
	Melbourne.	Swan Hill.
Dwalganup	Basal .. 47	4
	Upper .. 60	42
Mulwala	B. .. 60	17
	U. .. 70	75
Springhurst	62	B. .. 6
		U. .. 36
Bacchus Marsh	B. .. 12	12
	U. .. 60	12
Mt. Barker	72	B. .. 36
		U. .. 41
Nangeela	65	20
Burnerang	..	30
Macarthur	100	35
Tallarook	100	92

(3) *Factors Influencing Formation of Hard Seeds.*

From the foregoing observations on the occurrence of hard seeds in the plant, and in the strain, it is indicated that (1) length of development of the seed determines its capacity to become hard; (2) degree of drying influences its attainment of hardness. Experimental evidence on the importance of dehydration is summarised below.

Several workers, notably Helgeson (6) and Dutt and Thakurta (3) have noted the effect of degree of dehydration on the formation of hard seed. In both *Melilotus alba* and *Cajanus indica* it was found that where seeds which had reached maximum size were subjected to a certain amount of drying, germination could invariably ensue under favourable conditions, but on further drying, impermeability developed, which however could be reversed at once, by scarifying.

The effect of dehydration on full-sized seeds was therefore investigated, using different environments, and different times of exposure to one environment. Burrs were obtained from plants of the Dwalganup strain, which had been sown in December and had begun flowering in March. The seeds were 4 mm. long

and the testas deep red. Four quadruplicate samples of 25 were used in each of the tests in Table 7; the test begun 30th June, 1938, varied the rate of dehydration in one time; and the test begun 14th July, 1938, varied the time, the rate being constant.

TABLE 7.

Effect of dehydration on hard seed formation.

Date Commenced.	Length of Time.	Temp. Deg. Cent.	Relative Humidity.	Saturation Deficit.	Percentage Hard Seed.
			%		
30·6·38 ..	12 days ..	15	80	0·11	0
		15	0	0·54	40
		29	35	0·93	65
		29	0	1·41	75
14·7·38 ..	18 hours ..	29	0	1·41	15
	42 hours ..	29	0	1·41	17
	72 hours ..	29	0	1·41	35
	11 days ..	29	0	1·41	52

It is evident that in *Trifolium subterraneum,* the degree of dehydration controls the formation of hard seeds from previously permeable full-sized seeds. The factors in this dehydration are temperature, relative humidity, and the length of time during which they can act. The drying effect of high temperature and low relative humidity is expressed more briefly in terms of saturation deficit. It may therefore be said that the more intense the factors of saturation deficit and of time, the more hard seeds are formed in the burrs of any sufficiently mature plant.

(4) *Comparison of Hard and Soft Seeds.*

Storage in moist air will cause an obvious absorption of water on the soft type, but not on the hard which is unable to absorb water into the seed below the testa. After such a process, the hard seed will be black all over or at most, slightly pink at the hilum; the soft seed will be slightly larger, and purplish black except the area which includes the hilum, which will be distinctly pink.

Hard and soft seeds can be separated by this colour difference in samples of burr harvested later than usual in autumn after exposure to weather conditions of varying moisture since their ripening in December. This difference can also be readily observed in commercial seed stored several years under a low saturation deficit. In freshly dried burrs, however, the two types of seed are indistinguishable.

In order to determine the absorption of water vapour by hard and soft seed, samples of 200 seeds of both hard and soft types (distinguished by swelling capacity) were brought to constant weight in a desiccator and then exposed to room conditions

(70–80% R.H. and 16° C. + 2) and weighed periodically. Fig. 2 shows the results. In 30 days, the percentage increase of weight in the soft seeds was three times that in the hard. This effect is reversible.

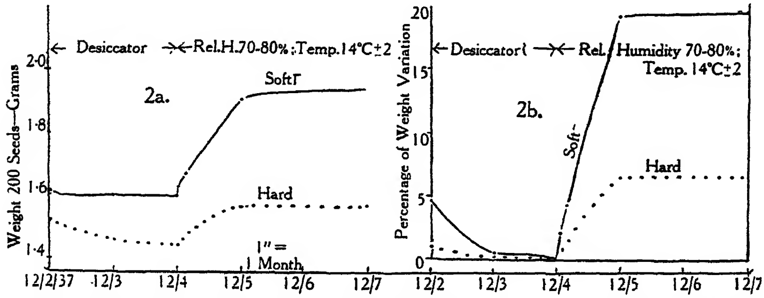

FIG. 2.—Absorption of water-vapour by hard and soft seeds; (*a*) showing relative weight changes; (*b*) showing changes in weight as a percentage of weight of each type, after two months in desiccator.

Hard seeds are evidently able to absorb some water vapour, and other tests show that water soluble dyes penetrated the matrix of hard seeds but no further, whereas they stained the whole testa in soft seeds. Since the anthocyan colour in the testa is situated below the impermeable layer, the addition of water to hard seeds might be expected to have no effect on colour, the matrix only, being affected. Conversely, the penetration of moisture in the soft seed lightens the testa colour and causes the characteristic pink appearance of the hilar region.

Soft seeds should generally be larger than hard because of their greater capacity to absorb water vapour. This was proved in a test on two-years old samples of seed, from burr collected in the field and from a commercial source. They were graded on a 2 mm. square mesh sieve, and those that passed through were put through a 2 mm. round mesh sieve. The percentages of soft seed in each grade are shown in Table 8.

TABLE 8.

Effect of seed size on soft seed percentage. (Samples of 200 seeds, each duplicated.)

Graded 2 mm. Square Mesh.	Percentage Soft.	
	Burr.	Commercial Seed.
	%	%
Graded > 2 mm. square mesh	35	94
,, < 2 mm. square mesh	14	88
,, < 2 mm. round mesh	5	79

The effect of the higher water content of the soft seed is evident in the soft seeds being about 15% heavier than the hard under ordinary storage conditions.

On a dry weight basis, however, soft seeds are about 20% lighter than hard in the same sample. Samples of 100 seeds of both hard and soft types, from single plants and bulk sources, were weighed, dried at 100° C. for four days, and weighed again. Taking one result, 100 hard seeds weighing 0.6535 grams, were dried to 0.6228 grams after a loss of 4.7% water; 100 soft seeds weighing 0.7123 grams were reduced to 0.4898 grams, after a loss of 30% water.

The higher dry matter content of the hard seed might be expected from the correlation of length of seed development with capacity for hardseededness. A long period of development should mean a high nutrient concentration and hence a high dry matter content, and the evidence supports this assumption.

The Softening of Hard Seeds, under Natural and Commercial Conditions.

The natural causes for the softening of hard seed in storage or soil are of interest to any concerned with the agricultural value of such seed. A review of the literature showed only isolated tests on single factors thought to be of importance—namely, temperature, mechanical pressure, humidity, alternation of wet and dry conditions.

Information was obtained on the occurrence of hard and soft seed in burrs harvested in March, 1936, by Mr. W. W. England, of Warncoort, Victoria, and received in May. Most of the burrs contained three or four seeds and separation of the results into those two classes showed that the percentage of soft seed in each did not differ significantly from a total of 20 per cent.

A later count of burrs containing 5, 4, 3, and 2 seeds gave similar results. There is no evidence to suggest that the occurrence of soft seed is influenced by the total number of seeds per burr. The staining of these seeds with osmic acid showed that most of the seeds which were soft, had been hard. The softening must have taken place between early January and May.

Under field conditions, burrs gave a certain percentage of soft seed at first, followed by decreasing amounts during the next months and years.

Conditions of storage affected the rate of softening in these burrs. The percentage of soft seed in burrs kept both dry, and wet occasionally, in a well-ventilated concrete building subject to daily fluctuations of 20–30°F., was significantly greater than in the rest of the burr stored in the soil laboratory with a daily

range of 2–5°F. Fig. 3 records that in the latter, even after two years, there is no significant increase from the original 20 per cent., whereas, in the former, the soft seed percentage has increased to 50 per cent. Similar burrs tested for four months under the range of conditions in Table 9 showed similar increased softening with wide daily temperature ranges.

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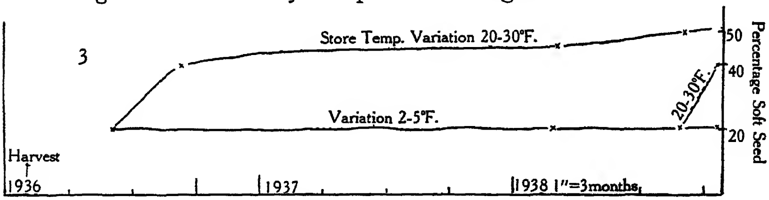


FIG. 3.—Rate of softening of seeds in burr, as affected by high and low daily ranges of temperatures.

TABLE 9.

Place.	Range of Temperatures.	Percentage of Soft Seeds after Period Aug. to Nov., 1938.
		%
Bulk store of 1938 burr ..	4° F.	18 (no increase on original test)
Oven at 29° C.	4° F.	26
Window ledge	60–110° F	34 (distinct increase)
Buried in soil in plot ..	40–120° F.	50 (distinct increase)

From the above observations, the importance of environment on softening in soil and storage is apparent. The possible factors of this environment are temperature, humidity, soil microflora that might assist in breaking down the outer part of the seedcoat, and alternate wetting and drying.

In order to test, under conditions of favourable culture and at a constant temperature of 28°C., the effect of the main types of microflora which may occur on and around the seedcoat of hard seeds, the following experiment was carried out. Moulds were favoured on a medium of glucose agar, root nodule bacteria on yeast mannite and other possible testa saprophytes on a silica gel. Four intensities of infection were used, viz., sterilized seeds, ordinary seeds, seeds with burr debris, and seeds with soil. About 200 seeds from the Warncoort burrs were used in each dish so that the first to germinate were those already soft.

In examining the results after four months and a year's treatment in such media, the first germination (about 20 per cent.) was ignored except to find the variation and only the later germinations analysed for significance. It was found that variation between both the different types and intensities of infection was not significant after these periods.

Fig. 4, of the amount of softening in time in the three media shows how gradual the softening is. The sudden rise in the last week in May occurred after an accidental rise in temperature

to 31° and then a fall to room temperature (10–15°C.) in a week-end. Otherwise, the temperature remained at 28°C. constant throughout the test. On 28th June, 1938, the seeds were transferred to fresh media, but no marked rise followed, despite the vigorous growth of fungi and bacteria colonies.

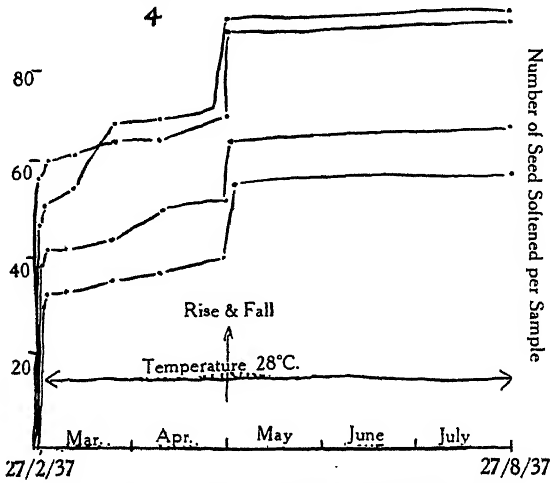


FIG. 4.—Rate of seed softening in Experiment 1 (effect of soil microflora), showing the effect of a wide temperature fluctuation.

Two strains of fat-splitting bacteria were tested on hard seeds in a broth medium, with negative results. Certain moulds and bacteria may become important after a longer period than a year but since much softening occurs within the year, the reason for this must lie with the remaining factors—temperature and moisture.

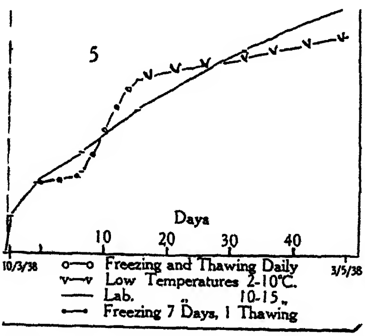
A second experiment was planned to include constant high and low temperatures and varying temperatures, with seeds continuously wet, and alternately wet and dry. In addition, seeds were tested in water changed daily, and in stagnant water contaminated with fragments of burr and hulls, and the germination was noted in burrs sown in soil in an outside plot, under normal conditions of fluctuating temperatures, moisture and microflora.

The standard error was the same as in the previous experiment, and hence the results of softening to be significant had to be more than 15 per cent. greater than the controls. Results from the 10th February to 8th April, 1937, show none significantly greater except possibly one which had been placed so as to get direct sun, and the widest temperature range possible in the laboratory (15°–40°C.). After the 8th April, it was moved out of sunshine and the softening rate became the same as most of the others.

At the end of the testing period, 8th March, 1938, the tests with two exceptions had softened about 47 per cent. The two exceptions (with 60 per cent. soft seed) had experienced the same accidental rise and fall in temperature as in the previous experiment.

These two experiments indicate that the fluctuation of temperatures is an important factor in inducing softening.

A third experiment was carried out to test the effect of freezing for seven days compared with freezing and thawing every day for seven days; and the effect of similar temperature range but not including freezing, with controls at laboratory temperature. Hard seeds of three successive harvests were used in each case, and the results showed decrease in sensitivity to temperature ranges above freezing point with increase of age. One long freezing softened the younger seeds more than the older, but a week of daily freezing and thawing to 15°C. softened a third of all the hard seeds irrespective of age. Fig. 5 shows the effect of temperature range on seed from 1937 burrs. Softening increases gradually, under 10°–15°C., while freezing over some days, or keeping at a range of 2°–10°C. retards the rate, and alternate freezing and thawing increases it conspicuously. Seed harvested in 1936 and 1935 reacted strongly to the softening effect of alternating freezing and thawing but, in contrast to 1937 seed, it was not softened at room temperatures (fig. 6).



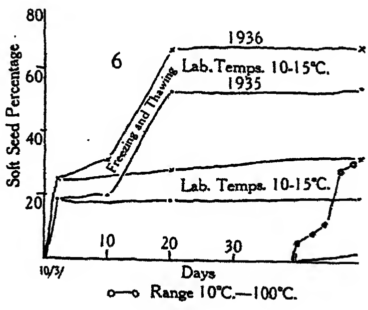


Fig. 5.—Rate of softening of seeds from 1937 burr, under various temperature ranges.
Fig. 6.—Comparison of rate of softening of seeds from burrs of 1935 and 1936 harvest, under conditions of freezing and thawing daily, for a week.

A fourth experiment was planned in order to try the effect of a wide temperature range on these less sensitive seeds. Such seeds softened considerably when subjected to such a high temperature of short duration as caused by contact with boiling water in which they are let cool. The results of repeated alternation of 10°–100° C. gave as much softening as the repeated freezing and thawing, viz. (fig. 6). The effect of a boiling water

application at night was evidenced in swollen seed the next morning.

The same result was found, though to a much less degree, with seed kept in the 28° C. incubator during the day and taken out into room temperature (10° C.) at night, as compared with no softening in seed kept constantly at 28° C.

The special effect of freezing and thawing, out of proportion to its temperature range; the increased influence of a given temperature range, the higher its mean level; and the increased softening with wider ranges and lack at constant temperatures; the modifying effect of age of hard seed on sensitivity, have all been noted experimentally. They point to the major role played by the temperature factor in the softening of hard seed under natural conditions.

It is well known that the high percentage of hard seeds usual in a burr sample of *Trifolium subterraneum* is very much reduced by the cleaning process in commercial seed production. Meadley (7) states that a variation of 14–45% soft seed in hand-cleaned samples from one small district was observed, whereas from machine-dressed lots, there was a range of 44–96%. This increase was entirely due to efficiency of the machine and the weather conditions at threshing. Hamly (4) discovered that the softening was due to the bouncing rather than to the scarifying action involved, and demonstrated in *Melilotus alba* and some clovers, the importance of an area in the seed more sensitive to stresses than elsewhere. Any break in the testa could be seen by a black stain developed with osmic acid. In the light of this knowledge, hard seeds (water tested) of subterranean clover were examined, and found to soften under the same method of shaking, after which treatment the softened ones showed the same type of staining with osmic acid, as recorded by Hamly.

Table 10 summarizes the effect of the osmic acid test on seeds after differing treatment. It confirms Hamly's results that (1) hard seeds, and soft seeds formed from hard, differ only in permeability of testa through splitting of outer cells, or by scarring by mechanical scratching. (2) That hard can be changed to soft by shaking. (3) That the area most susceptible to splitting is a special one—the strophiole. (4) That commercial seeds show far more soft seed through strophiole splitting than through external damage to the testa or because of original discontinuity of the impermeable layer round the testa. Table 11 shows the effect on softening of several mechanical methods of testa treatment, and the efficiency of the shaking or "bouncing" method.

Hence it is seen that the large increase in soft seeds found after the commercial threshing of subterranean clover burr is due to the bouncing action in the drum.

TABLE 10.

Identification of soft seed by Hamly's Osmic Acid method.

Source of Seed.	Result after five minutes in 1% Osmic Acid aq. soln.
1. Burr	Several with black spot at strophiole, and several with no marking
2. Commercial seed	Majority with black dot at strophiole, and few others with black scars elsewhere
3. Hard seed after 40 mins. conc. sulphuric acid	Black scars over testa
4. Hard seed shaken 100 times in bottle	As for (1)
5. White seed from burr ..	As for (1)

N.B.—The seeds that showed any black spot proved to be soft seed when put in water long enough to allow sufficient imbibition for swelling.

TABLE 11.

Effect of methods of Testa Abrasion on seed softening. (Duplicates of 25 burrs and 100 seeds.)

Treatment.	Per Cent. Soft Seed.
	%
1. Commercial seed	84
2. Seed from burr	20
3. Dehulled from burr	13
4. Dehulled from burr after conc. sulphuric acid for 40 minutes, but unstirred	18
5. Same, but stirred	52
6. Seed shaken 600 times in bottle	91

From the preceding information, in Sections II. and III., come the following facts:—(1) The importance of dehydration in hard seed formation; (2) prominence of fluctuating temperatures in softening hard seeds under field and storage conditions; (3) the influence of "bouncing" seed, on a special area—strophiole—during the preparation of commercial samples, in reducing the normally high hard seed content. A close examination of the seed in development and after maturity showed the internal reasons for these facts.

Relation of Seed Structure to Hardness.

So far it has been shown merely that hulled seeds are permeable to water before drying out, after which they may or may not be. Sections were taken to see the connection of the testa structure with the development of impermeability. Fig. *7a* shows the situation of the testa in a pod near full size. It was found that in later stages of the seed, the outer (Malpighian) cells went through a series of changes. At first they were colourless, and their distal ends were convex. Later a slight subcuticular layer (matrix) formed and the surface of the cell tips became flattened, then pink colour developed all through the cells. Withdrawal of the colour from the tops of the cells preceded the formation of a thicker matrix and a thin cuticle. The matrix and

decolourized cell tips appear as a lighter area above the darker cell walls beneath, without any definite translucent line at the junction. These changes in the testa, and also the accompanying crushing of the nutrient layer, and the lessening of the cell cavities after drying out, are shown in fig. 7 (*b-d*).

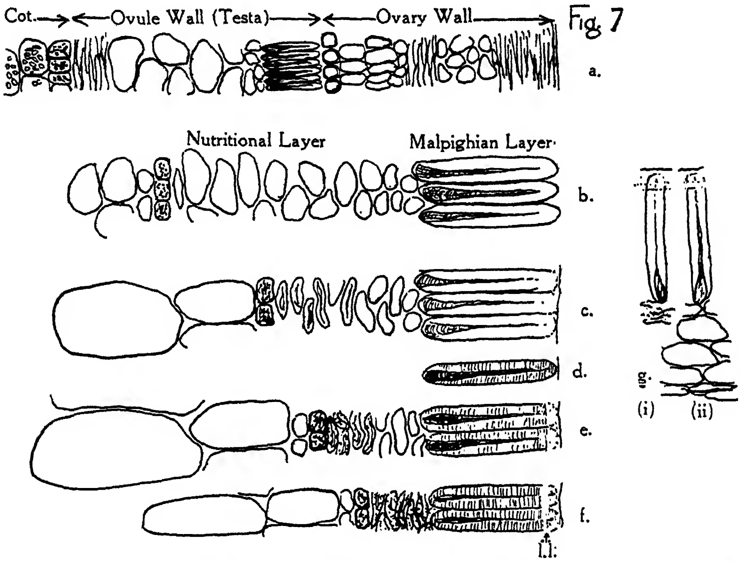


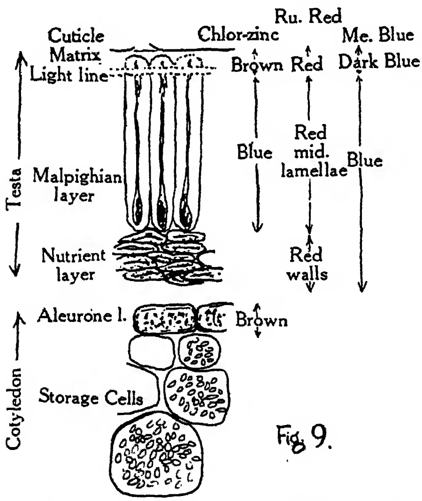
FIG. 7.—Longitudinal sections through the testa, showing (*a*) its position in the pod; (*b-f*) the changes in its cells from before the seed colours till it becomes hard; (*b*) Malpighian cells with rounded tips; (*c*) tips flattened and cuticle formed; (*d*) colour throughout cell; (*e*) colour withdrawn from tips; (*f*) reduction of cell lumens and formation of lightline, after drying of seed; (*g*) increase in depth of nutrient layer after contact with water.

A closer study of the time of development of the light line was made using well developed seeds and varying intensities of drying. Chlorzinc iodine and safranin were used as stains to differentiate cellulose from altered substances and hand sections were made of fresh seeds. Close microscopic examination showed that at the stage when the seed was beginning to colour externally, the Malpighian cells gave an even cellulose reaction (Plate XII., A). At the stage of full development, the stain was lighter at the tips. The same staining occurred in seeds that had been dried four days but were still soft. However, in hard seeds resulting from this treatment, there was a colourless band at the top with a light line more or less in evidence at its junction with the coloured lower cells. Soft or hard seeds from commercial samples showed the same type but with the light line more conspicuous, and the matrix yellow. (Plate XII., C.)

The strophiole must be described apart from the rest of the testa for it was found that the light line appears there before the seed is fully formed. This seems linked with an earlier

development of the Malpighian cells. In seeds about 1 mm. long, the strophiole cells were three times the length of the ordinary testa cells, more vacuolated, and had less conspicuous nuclei. At 2 mm. a more or less distinct light line was evident between the lower cell walls and a definite matrix (Plate XII., B). At this stage all the testa except this area was readily permeable. It was concluded that the presence of the light line indicated that of a substance impermeable to water, and though the light line was apparent at the strophiole before dehydration of the seed, its presence throughout was necessary for impermeability.

In mature seeds both hard and soft, the testa consists of two distinct layers of cells (fig. 9). The Malpighian layer is the deeper of the two, its cells being usually 3μ in diameter, and 24μ long. The outer surface of these is covered by a thin cuticle over a substance $1–2\mu$ thick which reacts to pectin dyes but does not swell on contact with water. That water can penetrate the cuticle and matrix is shown by the staining of these by such water soluble dyes as Methylene and Nile Blues and Crystal Violet.



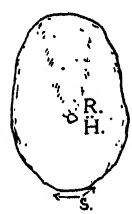


Fig. 10

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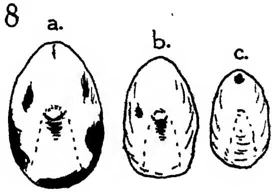

FIG. 8.—Staining reaction of seeds with osmic acid 1 per cent. for 1 minute; (*a*) at maximum size, there are scattered patches, and always at radicle tip; (*b*) dried seeds, still soft usually stain at radicle tip; (*c*) soft derived from hard develop circular stain at strophiole.

FIG. 9.—Diagram of the testa of a mature seed, with the colour reactions of some chemical tests.

FIG. 10.—Ventral view of a seed, showing hilum (*H*), radicle (*R*), and strophiole (*S*).

The walls of the upper ends of the Malpighian cells (termed "caps" by Hamly) are thickened by a material impermeable to water. This property is due to suberisation, as indicated by the cerinic acid reaction and other tests summarised in the following table, in which names at the head of columns refer to the layers in fig. 9.

TABLE 12.
Reactions of Testa.

Test.	Cuticle.	Matrix.	Suberized Layer.	Cellulose Walls.	Pectins of Nutrient Layer.
Phloroglucin and HCl. (Lignin)	..	..	..	Pink (∵antho-cyan)	
Cerinic acid (Suberin)	..	..	Yellow fat drops		
Chromic acid (Suberin)	..	..	The most resistant	Brown	
Crystal Violet (Fats)	Blue	Light violet	..	Lighter violet	
Schweitzers Reagent (Cellulose)	..	Swollen granular	..	Blue ..	Clear
Conc. H_2SO_4 and I. (Cellulose)	Dark	Dark ..	..	Mauve	Bluish to yellow walls
Chlor-zinc iodine (Cellulose)	..	..	..	Blue ..	Clear
HCl. then Amm. 2 per cent. (dissolves pectins)	..	Dissolves			
Ruthenium Red (Pectins)	..	Pink ..	..	Pink, mid lamellae	Pink
Methylene Blue (Pectins)	Violet	Bluish ..	..	Greenish	Blue

The junction between the suberised area and the unsuberised walls below is distinguishable as a translucent refractive line about 1μ thick occurring 3μ below the cuticle, and known as the "light line." The cause of this line has been shown by Hamly (4), to be due to the contact of substances of differing refractive indices.

Below the light line the walls of the Malpighian cells are of a cellulose nature, as seen from their reaction with chlorzinc iodine and sulphuric acid, but contain also certain substances that cause some reduction of osmic acid and a consequent black stain. The lumen of the cell decreases in width in the upper two-thirds of its length till it becomes about 0.3μ. Staining with osmic acid shows that several processes project vertically in the lumen just below the suberisation. In the dry seed, the cell contents are confined to a small deposit at the base of the cell, and noticeable only when stained by such as crystal violet or osmic acid. No chromatophores are visible as are characteristic of the Malpighian cells of *Albizzia.*

The inner layer of the testa consists of about five rows of dead, collapsed cells of the "nutrient layer." These have a great capacity for swelling in the presence of water, due to the

high proportion of pectin in their walls, c.f. fig. *7 g*. In *T. subterraneum,* the osteosclerid layer, occurring between nutrient and Malpighian layers, and typically formed of hourglass cells, is not sufficiently distinct to be separated from the nutrient layer. This is an exception to the general rule established by Pammell (8) for most leguminous genera including Trifolium.

The outer tissue of the cotyledon occasionally adheres to the testa, but as it consists of a single layer of large rectangular protein rich cells covering many rows of starch filled cells increasing in diameter 5–30μ it is easily distinguishable. A small amount of endosperm residue may also be observed at times.

The typical black colour of the testa is given by a blue water soluble substance contained in the lower unsuberised portions of the Malpighian layer, and distributed especially in the cell contents. This colour is an anthocyan, as it turns red with glacial acetic acid, and is comparable to that in the coloured spots of certain seeds of *Melilotus alba.* It is sensitive to pH change, going red with acid, and blue to brown with alkali. The phloroglucin test for lignin therefore gives a positive reaction in the cell walls in which this pigment occurs, not confirmed in seeds with colourless coats. Contact with zinc causes the testa to change to green. During absorption of water in a soft seed, the dye passes out in solution through cracks in the upper parts of the Malpighian cells and stains surrounding paper or water. The loss of some of the colouring matter in this way, combined with decrease in concentration of the remainder through the increased area of the testa, causes the change from the black of a dry seed to the pink of a swollen one. A hard seed will give no stain if wet, since there is no way the dye can escape.

Investigation of the effect of wetting on the testa layers showed that the collapsed "nutrient" layer expands up to about three times its normal thickness, and the Malpighian cells by about 10%. Both layers expand this latter amount in width. The great increase in size of the nutrient layer through imbibition of water is a reversible process. This may mean that temporary wetting of soft seeds in the field may cause little damage.

The effect of water on a whole soft seed is to cause swelling in a similar way to that in a free section but the collapsed layer may not expand in depth so much. The swelling and consequent increase in volume of the testa causes a gap (demonstrable on cutting sections of freshly swollen seed), to form between it and the cotyledons within. These in turn absorb water and expand about 30% in diameter when they again fit closely to the testa till after germination.

The testas of both hard and soft seeds show the same physical and chemical organisation. Their functional difference is solely due to permeability in various localities of the soft seed. The seed that has dried out but has not become hard is permeable in one or more irregular patches over the seed coat, generally

at or near the hilum, and is termed "original" soft seed. This permeability is due to incomplete formation of the suberinogenitic layer in the cell caps of those areas, as is evidenced by the absence of the light line. Such seeds may become hard by further drying out, which induces continuity of the impermeable layer.

Hard seeds become soft as a rule in one special locality, the strophiole, which is never permeable in original soft seed. This area is located on the long end of the seed near the hilum (fig. 10) and clefts through the light line will occur after sufficient local stress, e.g., fluctuating temperatures or bouncing. Present investigations on this clover, and local samples of lucerne, strawberry clover, white and sweet clover, confirm Hamly's discovery of the structural importance of the strophiole in the softening of hard seeds. Sections show that the Malpighian cells are bent in this area, not vertical as in the rest of the testa, and are 3–4 times as long. Table 13 and fig. 11 *a b.* It was seen previously that they develop more rapidly, even forming a light line before the seed dries out. This precocity is evidently linked with increased tension between the cells with consequent greater sensitivity to splitting

TABLE 13.
Size of Testa Cells.

—	Strophiole Cells.	Ordinary Testa Cells.
1. Depth cuticle to light line	18 μ	6 μ
2. Depth cuticle base Malpighian cells	140 μ	50 μ
3. Depth nutritional layer	20 μ	10 μ
4. Width Malpighian cells	6 μ	8–10 μ

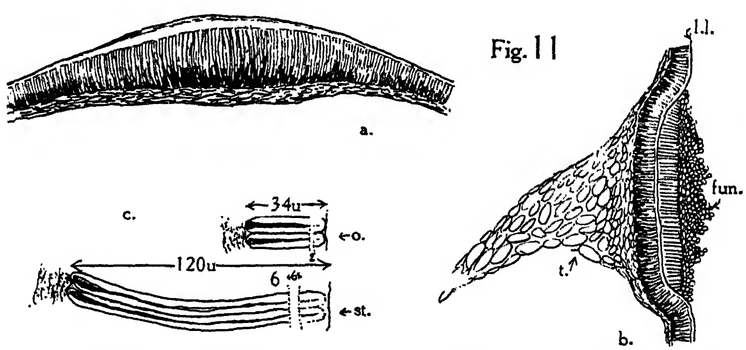

FIG. 11.—Longitudinal sections (*a*) through the strophiole of a hard seed, showing the increased size of the Malpighian cells, and their bent positions; (*b*) through the hilum, showing the continuity of the lightline, and the loose cells of the funicle, left after separation of the seed on drying; (*c*) comparison of Malpighian cells at strophiole and elsewhere in the testa. (fun. = funicular cells, l.l. = lightline, t. = tissue between radicle and cotyledons, st. = strophiole, o. = ordinary testa cells.)

than elsewhere. In Plate XII., F, the penetration of osmic acid at the strophiole of a softened seed is evident, and contrasts with that in a seed before drying (Plate XII., E).

Discussion.

The significance of hard seeds in the soil is important in all clovers and medicks, and is of special interest with reference to subterranean clover as a component of the pastures of southern Australia since this plant is an annual, depending for its persistence and spread on establishment from seed.

The plant dies at the onset of dry conditions in early summer, and if there has been successful burr production, the matured seed is capable of germination from December onwards, but only a small percentage is " soft." Heavy rain is sufficient to germinate this. But the dry weather that usually follows soon kills all or most of the seedlings. The same will occur after any further " breaks " in the hot dry conditions until with the autumn rains, a level of available moisture is reached which is adequate for establishment of seedlings. Observations show that normally there is no further germination till spring when a further burst of seedlings appears. Such irregular germinations will continue in the next years till all have softened. In some years, the first heavy rains occur in autumn, and therefore are followed by very heavy germination, and the hard seeds left, later give rise to seedlings for which there are no openings in the sward. If there are no heavy rains till winter, seedling establishment will be so poor owing to low temperatures, that further spring germination will be very useful in filling spaces in the " open " pastures.

Under some circumstances, the presence of hard seeds is an insurance, under others superfluous in the field, in others when the total number of soft seeds is small, is a definite deterrent to a quick even establishment of a thick stand.

Burial of the burr in subterranean clover has been regarded as a means of securing a larger number of soft seeds, and hence heavier seedling establishment. Present investigations have indicated that in well developed seeds, dried in the burr at the same time, those dried above ground will form a greater percentage of hard seeds, because of the higher saturation deficit; usually however, the buried seeds develop further because of a moister environment, and their later drying results in higher hardseededness, which is also generally of longer duration.

The fact of hardseededness seems to depend on a continuity of an impermeable suberinogenitic thickening with consequent evidence of a lightline, on the top of the Malpighian cells. This continuity is dependent on (1) the tendency of the cells to deposit the thickening according to an inherited capacity; (2) time for deposition; (3) degree of dehydration.

Workers with other legumes such as lupins and sweetclover, have shown the practicability of selecting more permeable seeded lines. In subterranean clover, the individual variation in hardseededness indicates the possibility of selection here also. Stevenson (9) indicates that the more permeable strains in *Melilotus alba* are so because of lack of continuity of the suberin round the testa.

The quality of hardseededness depends on the tendency of the strophiolar cells to split. The evidence is that long development of the seed before drying out, and high degree of drying results in hard seed of long duration. It is probable from this that this splitting is a function of (1) tension between cells; (2) thickness of suberin at shoulders of cell caps; (3) degree of dehydration.

Variations in this quality are the cause for the gradual softening through the years. The variability in rapidity of splitting at the strophiole under stress seems to be related more to conditions of ripening than to strain differences, and may be influenced by varying the time of flowering and ripening.

Preliminary observations have shown that reliable assessment of the establishment value of hard seeds of this clover, in Victoria, according to their germination by mid-April, and by September the next spring would be of use in the field.

This knowledge is of no importance in good quality commercial seed because of the efficiency in softening, of machine harvesting methods.

In fig. 12 the present knowledge on maturation and germinability of the seed of *T. subterraneum* is summarized. It corresponds closely to that of *Cajanus indica,* Dutt (3).

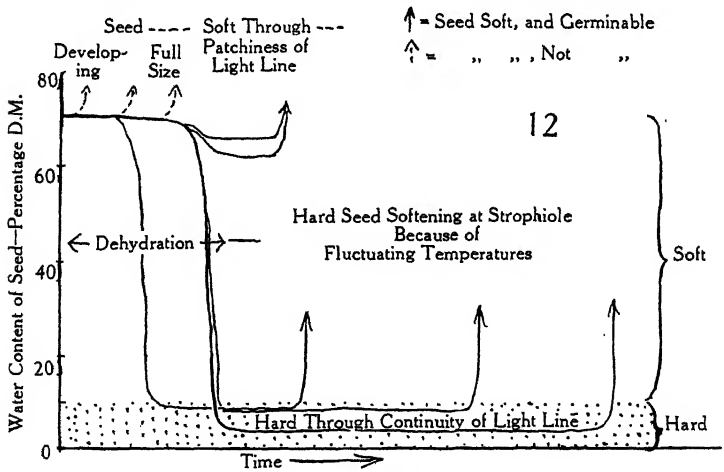

FIG. 12.—Summary of the behaviour of the seed of *Trifolium subterraneum* after growth to maximum size, indicating the relation of softness to germinability, and that of hardness to degree of dehydration, and to continuity of the lightline.

Further work may develop methods of controlling the process of seed development in a desired stage of maturity, e.g., a large percentage of original soft seeds, or of seeds capable of remaining hard for short or long periods.

Summary.

A full sized seed (not yet dried and fully mature) in the burr is always permeable over part of its surface, due to discontinuous development of the impermeable layer.

The drying out of these seeds results in some being sufficiently dried to develop a continuous layer of suberinogenitic character, and these form the "original" hard seeds in the burrs. Others, less dehydrated, remain permeable over part of the surface and form the "original" soft seeds. These may become hard on further drying.

Development of hard seeds is dependent on continuity of the suberin layer over the distal ends (caps) of the Malpighian cells of the testa. This continuity depends on degree of dehydration and thickness of deposition, which in turn are based on conditions of ripening in the burr.

The quality of the hardness, e.g., softening within a few weeks in the soil (pseudo-hardness), as compared with hardness lasting up to a year or more is controlled by the tension of the strophiole cell walls and the toughness of the suberin. These depend on rate of seed development, and degree of drying.

Hard seeds become soft through sensitivity of the strophiole cells to splitting under pressure. There is no reversion to hard on further drying, since a split between cells through the light line, once developed, is not sealed.

Softening of a hard seed through a split in the strophiole results from widely alternating temperatures or from freezing and thawing in the soil, and from the "bouncing" action in cleaning machinery.

Soft seeds from the burr differ from hard either in the presence of a split between cells at the strophiole, or in permeable patches in the rest of the testa. Those from commercial seed samples may also be caused by surface scratching.

Hard seeds are present in Victorian samples of subterranean clover burr to the extent of 55–90 per cent.; and in the commercial samples from 4–50 per cent. according to the roughness of the huller.

The percentage and quality of hard seeds produced by a plant of subterranean clover is controlled by seed development and degree of drying. The importance to these factors of time of flowering, panicle development, seed development above or below ground, time of burr drying, death of plant, time of harvesting, and individual plant variation within a strain, has been shown. It remains to get further data on the extent of softening in the first autumn, and to investigate the effect of strain apart from

time of flowering, and of selection within a strain, on the percentage and quality of hard seeds, before the practical value of field variation can be assessed.

Acknowledgments.

I wish to thank Professor S. M. Wadham for his guidance and most helpful criticism, the Department of Agriculture for access to much plant material at Burnley Gardens, Mr. G. Ogilvie for photographs, and other members of the staff of the School of Agriculture of the Melbourne University for practical help.

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Plates.

PLATE XI.

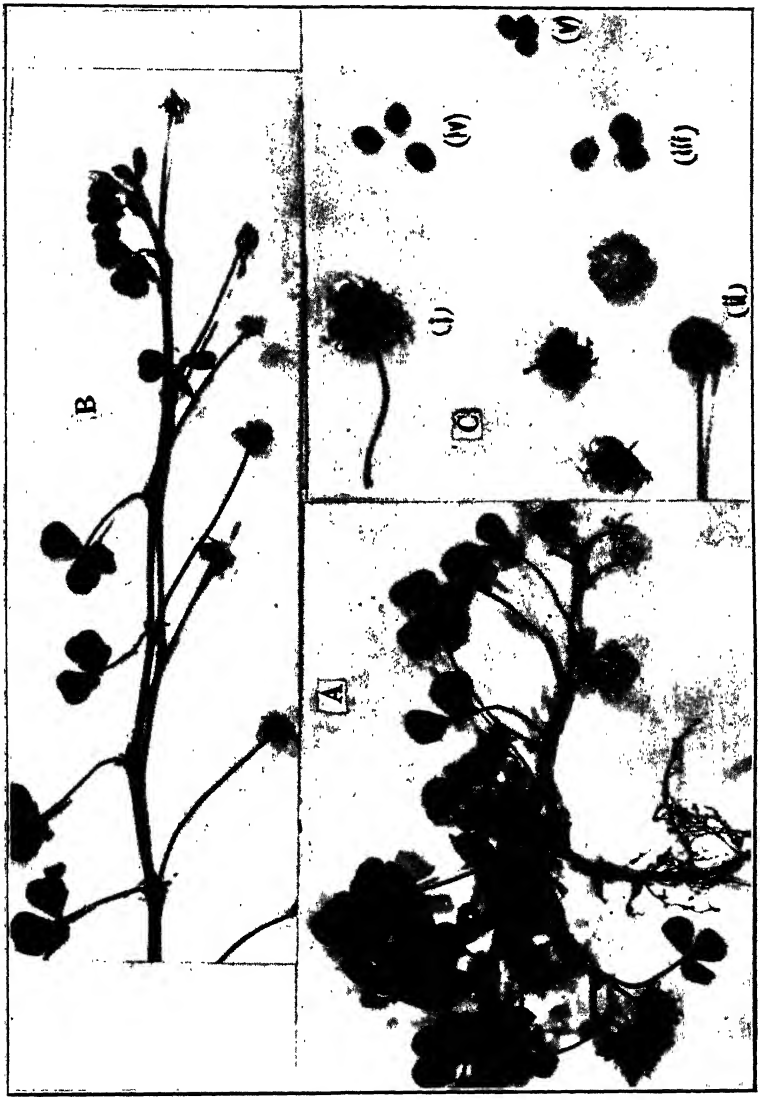
(A) A small plant of subterranean clover, showing prostrate habit, and formation of burrs along the runners.

(B) Portion of a well developed runner, showing the stages from erect panicle to full grown burr.

(C) (i) Burr developed below the surface; (ii) Various views of burrs developed above ground; (iii) Pods from one burr; (iv) Full grown seeds; (v) Dried seeds.

PLATE XII.

Sections: (A), through testa of half grown seed, showing nucleate, unthickened, Malpighian cells, × 250; (B), through strophiole of same, showing a conspicuous lightline, and much longer Malpighian cells, × 250; (C), through testa of a hard seed, showing development of colour (especially in the cell lumens), lightline, thickening of cells, and absence of distinct nuclei, × 250; (D), the same, with the thickness of matrix defined by the spread of osmic acid staining below the lightline from a nearby scratch, × 350; through hilum and strophiole of seeds after treatment with osmic acid; (E), in a fully developed seed, the black stain shows entry of acid round hilum, near strophiole and elsewhere, × 80; (F), in a hard seed turned soft, entry is at the strophiole only, × 80.



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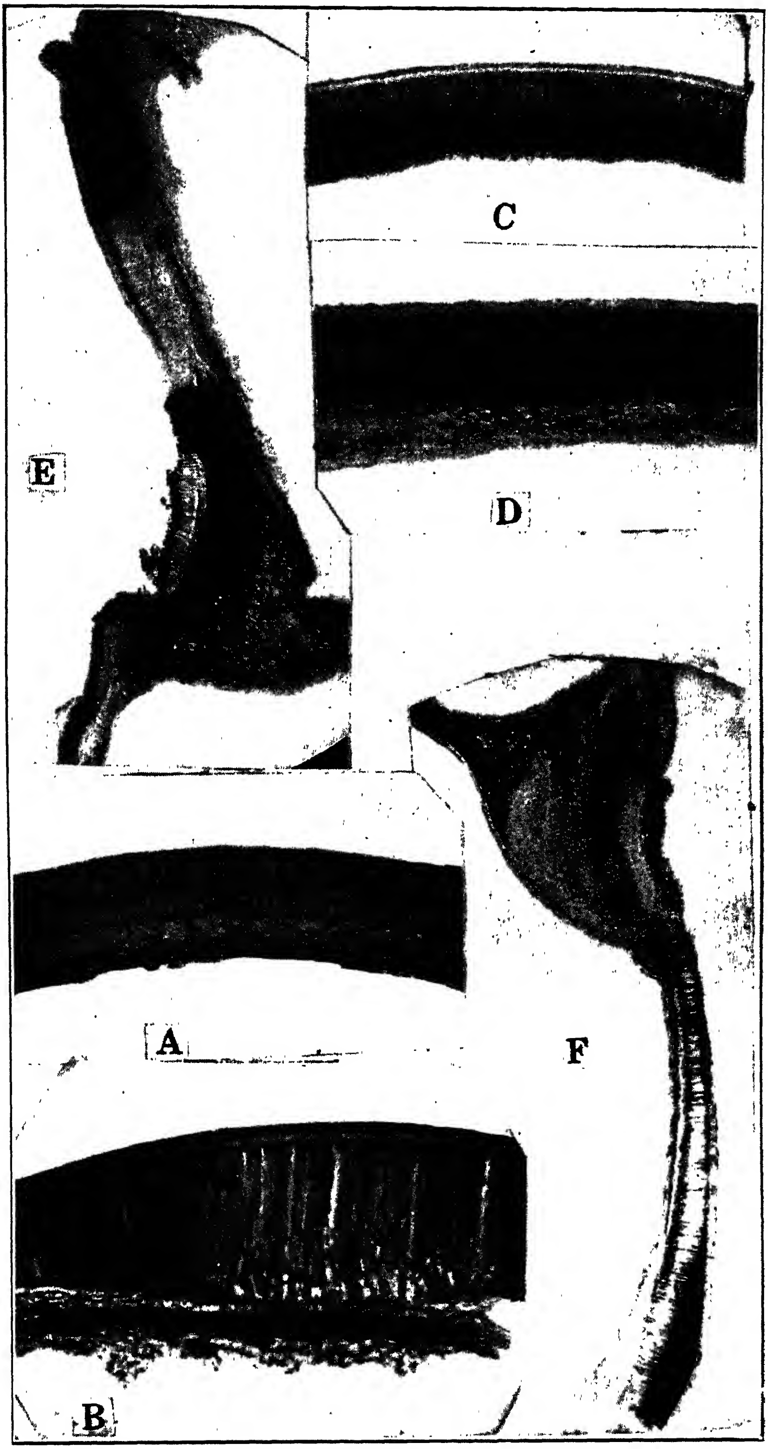


Aitken—Subterranean Clover.

[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. II., 1939.]

Art. X.—*Additional Notes on Petaline Vestiges in Eucalyptus.*

By A. D. HARDY.

[Read 10th November, 1938; issued separately, 24th July, 1939.]

Attention was directed by the author in a paper on "Petaline Vestiges in Eucalyptus" (Rept. A.N.Z.A.A.S. XXII, p. 372, 1935) to the fact that the bud-cap or operculum in *Eucalyptus* was not always a complete, hollow cone as it was generally thought to be, but was in a transitory stage, frequently bearing indications of petaline lobing at the apex. It was noted as significant that the comparatively few species then examined were of the section Corymbosae and therefore nearest to the reputed ancestor of the genus—*Angophora*.

Since that date, many species have been under observation and the 55 now recorded include some of such diverse character and habitat that they may be taken as a fair sample of the total species of the genus. Further examination has shown that the minute lobing which can be microscopically seen in the buds of many species is a character of frequent occurrence and one which, though not essential, is still worthy of inclusion in any extended description of this genus.

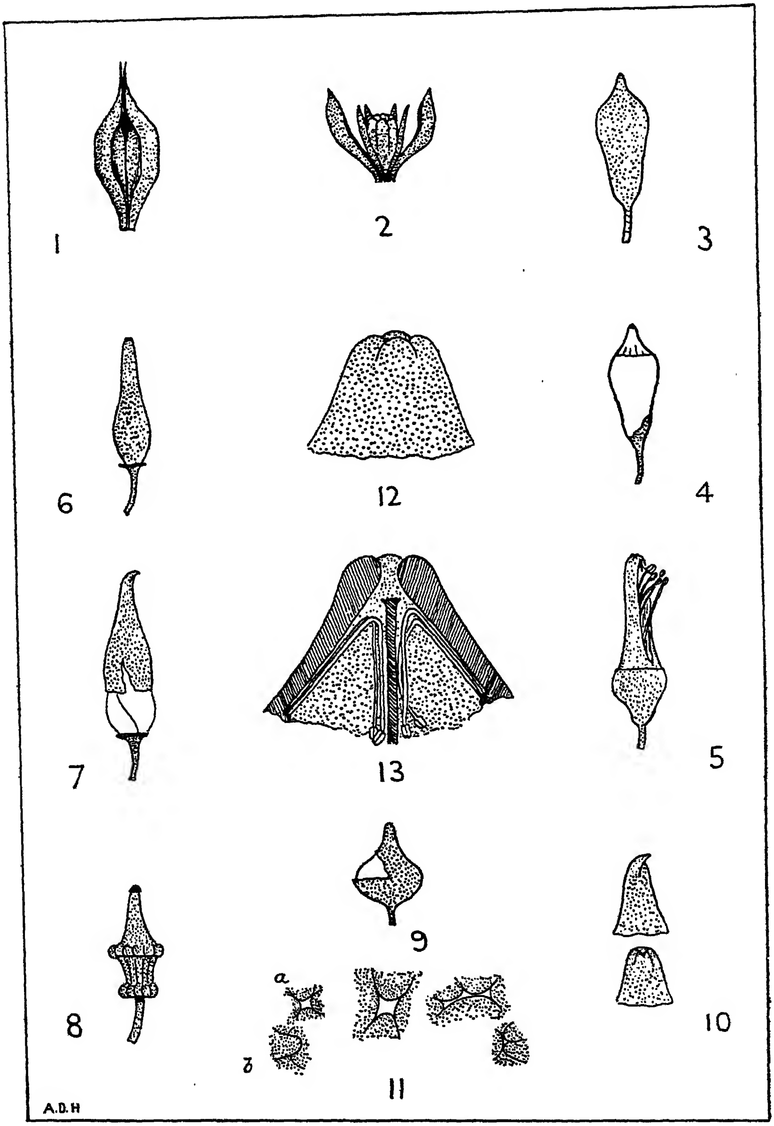
Although the lobing occurs in the same species in various localities, apparently unaffected by climate, altitude, aspect or soil, the arrangement of the lobes is as a rule irregular; the umbels on any tree may not be similarly affected nor in any umbel may the buds bear the indications equally. Macroscopically, the lobes are barely visible, the apex of the bud appearing as a rosy red point, but through a pocket lens, magnifying 10 diameters, they are seen to be a group of 2–4, rarely 5 papillae. Magnification of about 50 diameters reveals distinctly the lobes and, not infrequently, a pore (fig. 11), which communicates between the staminal chamber and the exterior. The pore may not be continuous; it may end indefinitely in the soft tissue of the bud-tip, or may be stopped by the stigma. A less common occurrence is seen in some buds of species which have a long-pointed operculum. In these, the apex may be bi-lobed, a superior lobe curving over like the upper mandible of a hawk's beak (fig. 10). This has been seen occasionally in ***rostrata***, ***leucoxylon*** and ***sideroxylon***. The ideal disposition is a symmetrical group of four lobes as in many young umbels of ***calophylla*** (figs. 12, 11A). The immature buds of calophylla (fig. 2), &c., have the apical lobing developed while still enclosed by the bracts of the umbel (fig. 1).

The fact that most of the examined opercula of matured or half-grown buds bore stomata is not enough, in itself, to decide whether the operculum is a fusion of calycine and corolline elements or is corolline only. In the absence of a calycine structure, the corolla in modified form may have learned to function as such. The scar at the base of the operculum (fig. 5, *platypus* var.), as seen in most species, is visible at a very early stage and persists till the bud's maturity, and it marks the line of circumcision whence the outer member of the modified floral envelope appears to have vanished. On many maturing buds of some species, and seen as a black spot on the apex, there appears to be the perched sepaline cap of the juvenile bud, e.g. *torquata* (fig. 8). Sometimes a portion of the epidermis is continuous from the thalamus tube, part of the way or even quite to the apex, interrupting the line of circumcision and preserving the unbroken profile curve of the bud (fig. 9, *rostrata* = *Camaldulensis*). The unbroken profile curve is a normal feature of *calophylla*, *ficifolia* (fig. 3), &c., and suggests a composite structure of the operculum in these species; but if, after maceration, the bud is skinned it sometimes appears as in fig. 4. If it were common to all species, it would make more acceptable a suggestion, made to me by the late Professor A. J. Ewart, that the lower part of the operculum might, after histological search, prove to be an extension of the thalamus tube.

If the lower part of the operculum is the concrescence of the members of a whorl, such concrescence appears to have occurred during the development of the primordial papillae.

The petaline feature described above cannot be seen satisfactorily in herbarium or shrivelled specimens. The buds must be freshly gathered, or studied on the tree (as in the present investigation with *ficifolia, calophylla, torquata, rostrata,* and *platypus* var., from infancy to maturity.

Something analogous can be seen in the calycine calyptra of some Papaveraceae and, of the Melastomaceae, *Pternandra cordata*. Of the former, the long calpytra of *Eschscholtzia Californica* (figs. 6, 7) is, from a basal circumcision, pushed up and off by the expanding petals, but this is frequently accompanied by a partial splitting from the base upwards. It has a minutely lobed apex in which, when bi-lobed, the "hawk-beak" arrangement occurs. In *Papaver nudicaule* var. *radicata*, there is a tendency to throw off the sepals in the form of a cap, which are often seen perched on the expanding corolla and parted at the base only. A rare occurrence in *Eucalyptus* is that which was seen in seven buds of *platypus* var. (fig. 5). In these cases, all on one tree, the buds had partly opened by a longitudinal fissure in the operculum, from a little above the base to or nearly to the apex, and through this opening a few of the crimson stamens protruded; but this may have been due to mechanical injury, as other buds were not ready for normal opening.



FIGS. 1-13.

Because of the importance of the operculum in systematic work on this genus, more interest attaches to the bud than perhaps to that of any other species. The subject seems to demand, or at least deserve more study, especially from a histological point of view.

The following species have been examined, but the extra-Victorian species have been observed only in cultivation, in Victoria. With the exception of *globulus* and *bicostata,* in which the tuberculation of the bud made observation difficult, the listed species exhibited petaline vestiges more or less distinctly. Eucalyptus: *albens, Australiana* (*radiata,* var. *australiana,* Blakely), *Bosistoana, Behriana, bicolor, botryoides, cinerea. cinerea,* var. *multiflora* (*cephalocarpa,* Blakely), *camphora, calophylla, calycogona, citriodora, cladocalyx, pauciflora, cornuta, diversicolor, dives, dumosa, elaeophora, erythronema, fastigata, gigantea, globulus, globulus,* var. *bicostata* (*bicostata,* Maiden, Blakely and Simmonds), *goniocalyx, gracilis, haemastoma, hemiphloia Muelleriana, nitens, paniculata, Preissiana, platypus* (var.), *polyanthemos, punctata, radiata, regnans, rostrata* (*Camaldulensis,* var. *brevirostris,* Dehn.). *rubida, sideroxylon, leucoxylon Smithii, stellulata,* x *Studleyensis, Stuartiana, tereticornis* (*Camaldulensis,* Dehn.), *torquata, uncinata, viminalis, viridis.*

EXPLANATION OF FIGURES.

FIG. 1.—Bracts enclosing an umbel of *Eucalyptus ficifolia.*

FIG. 2.—Young umbel emerging.

FIG. 3.—Mature bud of *E. ficifolia.* No circumcision scar.

FIG. 4.—Bud of *E. ficifolia* after maceration, showing base line of operculum.

FIG. 5.—Bud of *E. platypus* (var.). Operculum ruptured longitudinally, showing extruded stamens.

FIG. 6.—*Eschscholtzia californica,* with calycine calyptra, analogous to the caducous "outer operculum" of *Eucalyptus.*

FIG. 7.—Same, showing calyptra freed by basal circumcision; and bi-lobed at apex as occasionally seen in this species and in *Eucalyptus.*

FIG. 8.—Bud of *Euc. torquata,* nearly mature, showing the minute sepaline cap ("outer operculum") perched on apex.

FIG. 9.—*E. rostrata* (*E. camaldulensis,* var. *brevirostris*). A bud (of several seen) showing continuation of the epidermis of the thalamus tube over part of the operculum.

FIG. 10.—Bird-beaked arrangement seen in some specimens of long-pointed opercula, e.g., *E. sideroxylon, E. leucoxylon, E. oleosa, E. torquata* (cf. Fig. 7).

FIG. 11.—Diagrammatic representation of various pores seen from above: (*a*) Symmetrical arrangement as infrequently seen. (*b*) Bird-beaked apex (cf. Fig. 10).

FIG. 12.—Greatly magnified apex of operculum as seen in specimens of *E. ficifolia, E. calophylla, E. platypus* (var.), *E. rostrata, E. regnans, E. viminalis,* &c.

FIG. 13.—Long. sect. through apex of bud of *E. ficifolia,* showing pore as infrequently seen.

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Art. XI.—*The Devonian Rugose Corals of Lilydale and Loyola, Victoria.*

By DOROTHY HILL, M.Sc. (Qld.), Ph.D. (Cantab.).

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(Plates XIII–XVI.)

Summary.

In this paper the Rugosa of Lilydale and Loyola are described and figured, and a review is given of the genera and families to which they are assigned. Remarks on new septal structures are included. Both faunas, previously supposed Upper Silurian, are shown to be Devonian; that of Loyola is probably Lower Devonian, and that of Lilydale older than Upper Devonian.

The Faunas and their Ages.

Corals have been known from Lilydale since 1890, when Etheridge described *Favosites grandipora,* referring to the age as Upper Silurian. The Rugosa from Lilydale have been described by Chapman (1914, 1925, 1931). Rugosa from Loyola were first described by Dun (1898), later by Etheridge (1899) and Chapman (1914) as Upper Silurian. An investigation of the stromatoporoid faunas of Lilydale and Loyola has suggested to Miss Ripper (1933, 1937 *a, b,* 1938) that both are Devonian (1938, p. 241); at Lilydale there is a high proportion of Lower and Middle Devonian species, but the Loyola fauna has Silurian affinities. The present study of the Rugose coral faunas indicates that both are Devonian; that of Loyola is probably Lower Devonian, and that of Lilydale either Lower or Middle Devonian. All the genera involved are characteristic of the Devonian; none has clear Silurian affinities. This determination of the age was made possible by recent work in Europe, notably by Lang and Smith, and Wedekind (see bibliography). For the purposes of the investigation all available figures of the species of the genera involved and of those genera which appear to be related have been studied, and the results of this study are included in the remarks on families and genera. The Tabulate corals are at present being investigated by O. A. Jones and myself, and so far support the conclusions expressed above

The Rugosa from Lilydale are:—

Prismatophyllum chalkii (Chapman).
Prismatophyllum stevensi (Chapman).
Mictophyllum cresswelli (Chapman).
Lyrielasma subcaespitosum (Chapman).

Prismatophyllum and *Mictophyllum* are known elsewhere only from the Devonian. *Lyrielasma* is a new genus with affinities to Lower and Middle Devonian species. From these Rugosa it is difficult to give a more precise age to the Lilydale limestone than Devonian, as none of the species show very close similarity to species known overseas. The presence of *Heliolites,* however, indicates that the fauna is older than Upper Devonian. None of the species occurs in either the Upper Silurian coral faunas of Yass, New South Wales, or the Middle Devonian fauna of Buchan, Victoria, but *L. subcaespitosum* is found at Loyola. The Lilydale coral locality is the quarry at Cave Hill.

The Rugosa from LOYOLA are:—

Acanthophyllum mansfieldense (Dun).
Phillipsastraea speciosa Chapman.
Phillipsastraea sp. indet.
Trapezophyllum elegantulum (Dun).
Thamnophyllum reclinatum sp. nov.
Loyolophyllum cresswelli Chapman.
Lyrielasma subcaespitosum (Chapman).
"*Cystiphyllum*" sp.

Acanthophyllum and *Thamnophyllum* are known only from the Devonian, *Phillipsastraea* is predominantly Devonian although two species have been recorded from the Silurian. *Trapezophyllum* and *Loyolophyllum* are found only at Loyola, but the former has affinities to the Devonian *Disphyllum* (*Phacellophyllum*), and the latter to the Devonian *Fasciphyllum* Schlüter. *Lyrielasma* occurs elsewhere at Lilydale, and cystimorphs are either Silurian or Devonian. It seems clear that this fauna is Devonian. The species *A. mansfieldense* and *T. reclinatum* are very similar to Lower Devonian species from Bohemia, and it is probable therefore that the Loyola fauna is Lower Devonian. *L. subcaespitosum* occurs at Lilydale, and *T. reclinatum* is very similar to *T. mitchellensis* (Etheridge) from Sandy's Creek, on the Mitchell River, Victoria, a locality formerly thought to be Upper Silurian, but I consider both these species indicate the Devonian. None of the other species are known elsewhere in Australia, from either the Upper Silurian Yass beds, or the Middle Devonian of Buchan or Taemas.

Family ACANTHOPHYLLIDAE.

Type Genus: ACANTHOPHYLLUM Dybowski.

Simple Rugosa with a wide dissepimentarium of small, highly arched dissepiments, long septa frequently modified, and numerous, shallowy concave tabulae deepened at the axis. The major septa are unequal, but are never amplexoid, and a metaseptum is the longest.

RANGE.—In Europe the family occurs somewhat rarely in the Lower Devonian, is very common in the Middle Devonian, and rare or absent in the Upper Devonian. There are many undescribed species in the Devonian of Australia. In the Downtonian of Russia, *Neocystiphyllum keyserlingi* (Dybowski; Soschkina, 1937, pl. xix, figs. 3, 4) may be a representative. Its apparent absence from America and Asia is surprising.

REMARKS.—This family comprises those forms related to *Cyathophyllum heterophyllum* Edwards and Haime. It is extremely difficult to decide whether the group is best divided into genera, or into sub-genera, or treated as one genus; or even on the limits of species within the group. Wedekind and others at Marburg have included German Middle Devonian members of the group under the following generic or sub-generic names:—*Mesophylloides* Wedekind (1921, p. 51), *Ptenophyllum* Wedekind (1924, p. 36), *Astrophyllum* Wedekind (1924, p. 46), *Rhopalophyllum* Wedekind (1924, p. 52), *Stenophyllum* Amanshauser in Wedekind (1925, p. 9, genotype *S. diluvianum* Amanshauser), and *Neostringophyllum* Wedekind (1921, p. 16, genotpye *N. ultimum* Wedekind). To evaluate these genera and their species in relation to one another and to the genera and species founded earlier from the same fauna would require a new revision of the German Middle Devonian Rugosa, and this of course could only be undertaken by someone to whom all the types are available. Meanwhile I refer to *Acanthophyllum* Dybowski all forms which I consider to belong to the group, *Acanthophyllum* being the earliest generic name specially applied to any of its members—viz., *Cyathophyllum heterophyllum* Edwards and Haime, and leave unsolved the taxonomic problems created by Wedekind's insufficient study of prior species and genera.

The following figures of Lower Devonian species appear to me to indicate membership of the family:—*Cyathophyllum* cf. *heterophyllum* E. & H., Charlesworth, 1914, pl. xxxi, fig. 6, Eastern Alps; *Pseudochonophyllum pseudohelianthoides* Scherzer, Sochkina, 1937, pl. xviii, figs. 1–4, Urals; *Cyathophyllum baculoides* Barrande, Počta, 1902, pl. 104, fig. 5, Koněprus, Bohemia, and Le Maitre, 1934, pl. v., fig. 18, Chalonnes, France; *Cyathophyllum ungeri* Penecke, 1894, p. viii, figs. 9–10, Graz, Austria.

Most of the Middle Devonian specimens figured by authors as *Cyathophyllum heterophyllum* and *C. torquatum* belong to the group, as also those figured by Wedekind under the generic and sub-generic names listed above. In addition, the following figures probably represent the group:—*Hallia pengellyi* Edwards and Haime, 1853, pl. xlix, fig. 6, Torquay; *Cyathophyllum obtortum* Edwards and Haime, 1853, pl. xlix, fig. 7, Torquay, and *Cyathophyllum roemeri* Edwards and Haime, 1853, pl. 1, fig. 3, Torquay.

I have not seen any figures of specimens from the Upper Devonian which could represent members of the family.

Genus ACANTHOPHYLLUM Dybowski.

Acanthophyllum Dybowski, 1873, p. 339; 1874, p. 493.

Rhopalophyllum Wedekind, 1924, p. 52.

Genosyntypes: Cyathophyllum heterophyllum Edwards and Haime, 1851, pl. x, figs. 1*a–c*. Devonian, Eifel.

Acanthophyllum linarsönii Dybowski, 1874, p. 493, pl. v, figs. 1–1*a*, Silurian, Insel Oesel. [possibly = *Spongophylloides* sp.]

GENOLECTOTYPE.—Chosen Schlüter, 1889, p. 38: *Cyathophyllum heterophyllum* Edwards and Haime.

DIAGNOSIS.—Large, simple Rugosa with a wide dissepimentarium of small, highly arched dissepiments, with shallowly concave, axially deepened tabulae, and with long, but unequal major septa. The axial ends of the major septa are arranged in groups in the tabularium, and are straight, or curved vortically, the curvature differing in degree from group to group; the cardinal septum is typically short, and one septum, not a protoseptum, extends to the axis. The septa show different types of modification; they are frequently much dilated, either in the dissepimentarium, or more rarely in the tabularium, or in both; towards the periphery they may be thin and lined with lateral dissepiments; in the tabularium they are sometimes waved and carinate.

RANGE.—Fairly common in the Lower Devonian of Europe, and very common in the Middle Devonian of Europe. Lower and Middle Devonian of Victoria.

REMARKS.—I have examined Edwards and Haime's figured syntype of *C. heterophyllum,* now in the Natural History Museum, Paris. The unpolished vertical section shows concave, axially deepened tabulae, small, arched dissepiments, and vertical sections of the axial ends of the septa with the waves and carinae characteristic of the specimens figured by Wedekind (1924, figs. 76-98) as *Rhopalophyllum.* The major septa are more dilated than the minor septa, and both orders attenuate towards periphery and axis. A transverse section of this syntype was not available, but I consider the vertical section is sufficient to prove its identity with the *Cyathophyllum heterophyllum* E. & H. of Frech (1886, pl. vi, fig. 7), from the Upper *Calceola* beds of Auburg near Gerolstein, which was refigured by Wedekind (1924, fig. 96) as a syntype of his new sub-genus *Rhopalophyllum* of his new genus *Ptenophyllum.* By my here chosing *C. heterophyllum* E. & H., Frech as genolectotype of *Rhopalophyllum, Rhopalophyllum* becomes a synonym of *Acanthophyllum.* Other genera described by Wedekind under his family Ptenophyllidae may well be synonyms of *Acanthophyllum* (see remarks on the Family Acanthophyllidae).

Acanthophyllum mansfieldense (Dun).

(Plate XV, figs. 1–3.)

Cyathophyllum mansfieldense Dun, 1898, p. 87, pl. iii, figs. 3–4; Griffith's Quarry, Loyola, near Mansfield.

Holotype.—George Sweet Collection, National Museum, Melbourne.

Diagnosis.—*Acanthophyllum* with septa carinate and but slightly curved in the dissepimentarium, the dilatation periodically increasing wedge-wise towards the periphery and then being suddenly reduced.

Description.—This description is based on two fragments collected by Miss E. Ripper, 1646 and 1653 in the Department of Geology, Melbourne University. The first has a diameter of 38 mm., and the second of 15 mm. From these it is inferred that the corallum is simple, and turbinate or trochoid. There are 52 septa, the 26 minor septa being equal in length and extending three-quarters of the way to the axis. The major septa extend unequally into the tabularium; the cardinal septum is the shortest, and none of the proto-septa are predominant in length, the longest septum being a meta-septum in one of the cardinal quadrants. Those parts of the septa in the tabularium may be straight, or turned aside at their axial edges, and waved or carinate, and sometimes swollen slightly at the axial edge; dilatation is not great. Those parts of the septa in the dissepimentarium are dilated, and in transverse section the dilitation would appear to be periodic. Thus the septa thicken outwards like wedges for some distance, when there is a general and sudden reduction, so that wide interseptal loculi appear; then again they thicken outwards wedgewise, and again a sudden reduction occurs. Thus successive but rather irregular stereozones are obtained. The septa are dilated and in contact at the periphery. The fibres of the septal trabeculae are directed obliquely from the median plane of the septum. The floor of the tabularium is slightly concave, with an axial deepening; the tabellae are incomplete, closely placed and shallowly arched. The dissepiments are small and rather highly arched, numerous, slightly inclined at the periphery, but becoming steeply inclined near the tabularium, and are frequently of angular transverse section.

Remarks.—In the nature of the dilatation of its septa, this species is exactly similar to *Acanthophyllum baculoides* (Barrande in Počta, 1902, pl. 104, fig. 5) from F_2 (Coblenzian), Koněprus, Bohemia, and from the limestone of Chalonnes, France, which Le Maitre (1934) has argued is at the limit between the Coblenzian (top of the Lower Devonian) and Couvinian (base of the Middle Devonian). But *A. baculoides* in contrast to *A. mansfieldense*, shows marked rotation of the septa in the tabularium. *A. baculoides* and *A. mansfieldense* have

a different type of septal dilatation from all other *Acanthophyllum,* in that the septa increase in thickness wedgewise to the periphery, with or without intermittent setbacks; in most *Acanthophyllum* the septa are spindled, dilatation decreasing towards the periphery as well as towards the axis. Connected with these two types of dilatation is the appearance of two types of dissepiment-like plates derived from the septal invaginations. In *A. baculoides* where the dilatation increases towards the periphery, the septa may break down into naic plates (Hill, 1935, p. 502); in *A. richteri* (Wedekind, 1921, pl. i, fig. 2) etc. they are lined with lateral dissepiments.

Family DISPHYLLIDAE.

Type Genus: DISPHYLLUM de Fromentel, 1861, p. 302.

Rugose corals with septa which tend to be dilated and to develop trabecular carinae, and to have an area of divergence of the septal trabeculae; with flat or gently curved axial tabulae, usually complete, often supplemented by inclined, periaxial tabulae; and with globose dissepiments which may be arranged in a vertical series of horse-shoes to form the wall of the tabularium.

RANGE.—Devonian of Europe, America, Australia, and Asia.

REMARKS.

I.—GENERAL.

The group has been admirably expounded by Lang and Smith (1935*b*) who have recognized five genera and discussed twenty of their synonyms, including one genomorph. The phaceloid *Disphyllum* persists throughout the Devonian, showing a great variety of structure, and its genomorph {*Phacellophyllum*} Gürich (1909, p. 102) also. The phaceloid *Thamnophyllum* Penecke (1894, p. 593) is common in the Lower Devonian and Couvinian of Styria. The cerioid *Prismatophyllum* (Simpson, 1900, p. 218) occurs first in the Lower Devonian, but is more common in the Middle and Upper Devonian. The plocoid *Phillipsastraea* d'Orbigny (1849, p. 12) has been recorded from the Upper Silurian of Estonia (see p. 236). A Lower Devonian species from Bohemia was called *Phillipsastraea* by Počta (1902, p. 158), but the genus had a widespread development in the Middle and Upper Devonian. *Macgeea* Webster (1889, p. 710), a genus of solitary or weakly compound species, is known at present only from the Givetian and Frasnian. A sixth genus is here included, the cerioid *Trapezophyllum* Etheridge (1899, p. 32) from the Lower(?) Devonian of Victoria, which has the same morphological relation to *Prismatophyllum* as {*Phacellophyllum*} has to *Disphyllum*.

The Disphyllidae are extremely important in Australian Devonian faunas, and in order to facilitate comparison of the Australian species with those from known horizons overseas, and thus to ascertain their stratigraphical value, the family is reviewed in this paper. *Disphyllum* and *Macgeea* are discussed immediately, but *Thamnophyllum, Prismatophyllum, Trapezophyllum* and *Phillipsastraea* all have species occurring at Lilydale or Loyola, and are discussed under their separate generic headings.

II.—MORPHOLOGY AND STRATIGRAPHY OF DISPHYLLUM.

A.—Tabularium.

The arrangement of the plates in the tabularium is very varied, and six patterns are recognized. Their relation is proved by more than one of them occurring in the same corallum, and by their association with similar septal and dissepimental characters.

1. In the American Couvinian *panicum* (Winchell, Ehlers and White, 1932, p. 93, pl. i, fig. 1, pl. iii, figs. 3–5, pl. iv, figs. 3–4, pl. v) there is an inner series of unequal tabulae, sometimes complete and horizontal, domed or saucered, and an outer series of tabellae inclined towards the axis. In the co-existent *elongatum* (Simpson, 1900, fig. 42) the outer series is unimportant.

2. In the European Givetian and Frasnian *goldfussi* (Geinitz, Lang and Smith 1935*b*, pl. xxxv, figs. 4, 8) and *caespitosum* (Goldfuss, Lang and Smith, 1935*b*, p. 573) there is an inner zone of very shallowly domed plates, and a narrower outer area of large inclined plates, the outer zone forming a higher part of the calicular floor than the inner.

3. In the European Givetian and Frasnian *trigemme* (Quenstedt, Lang and Smith, 1935*b*, p. 575) this second type is modified so that the plates of the inner area are flat.

4. In the European Upper Givetian or Lower Frasnian *aequiseptatum* (Edwards and Haime, Lang and Smith, 1935*b*, pl. xxxv, fig. 14) the inner series is of incomplete unequal, but rather globose plates inclined towards the axis. The Australian *virgatum* (Hinde, Hill 1936*b*, pl. i, fig. 3) and *depressum* (Hinde, Hill, 1936*b*, pl. i, figs. 4, 7) of similar age belong to this group.

5. In the European Givetian *geinitzi* Lang and Smith, (1936*b*, pl. xxxvi, fig. 3) the outer series is not developed, and the complete tabulae are shallow domes.

6. In the European Frasnian *minus* (Roemer, Lang and Smith, 1936*b*, pl. xxxv, fig. 3, Ma 1937, pl. ii, fig. 1) the outer series becomes unimportant, and an axial series of flatly domed tabellae is superimposed on the inner series of the *goldfussi* type.

B.—Dissepimentarium.

1. In the American Couvinian *arundinaceum* (Billings, Lang and Smith, 1936*b*, p. 561) the interseptal loculi are closed by septal dilatation, except for the spaces within a single series of horse-shoe dissepiments.

2. In the American Couvinian *panicum* and *elongatum*, and the European Givetian and Frasnian *goldfussi*, the dissepiments are globose and inclined towards the axis, the inner series being more inclined than the outer, which also tend to be larger.

3. In the European Givetian and Frasnian *Phacellophyllum caespitosum* and *Phacellophyllum trigemme* there is a single outer series of flat dissepiments and a single inner series of horse-shoe dissepiments.

4. In the European Frasnian *minus* there is only a series of horse-shoe dissepiments.

5. In the European Givetian *geinitzi* there is one or sometimes two series of rather globose or highly inclined dissepiments.

C.—Septa.

1. In the American Couvinian *arundinaceum* the septa are much dilated, the dilatation decreasing sharply in the tabularium.

2. In the American Couvinian *arundinaceum* and *panicum* the septa have trabecular carinae, curved at right angles to the dissepiments.

3. In the European Givetian and Frasnian *caespitosum*, *trigemme* and *minus* the septa have trabecular expansions over the horse-shoe dissepiments; the curvature of the trabeculae being at right angles to the surfaces of the horse-shoes.

4. In the Australian Upper Givetian or Frasnian *depressum* and *virgatum*, the septa are dilated and in contact at the periphery, and through most of the dissepimentarium, but attenuate towards the axis.

5. In the European Givetian and Frasnian *goldfussi* and *aequiseptatum*, the septa are but slightly thickened, more so towards the periphery, and may be slightly sinuous.

III.—MACGEEA.

Macgeea has a type of septal dilatation (Lang and Smith, 1935*b*, p. 577) not seen in *Disphyllum*, but relationship is proved by the area of divergence in the septal trabeculae corresponding in position with the horse-shoe dissepiments (*loc. cit.* pl. xxxvii, figs. 8, 9), by the dissepimentarium, which resembles that of *Phacellophyllum*, and by the tabularium, which is a modification of the *minus* and *aequiseptatum* types.

Genus THAMNOPHYLLUM Penecke.

Thamnophyllum Penecke, 1894, p. 593.

Thamnophyllum; Lang and Smith, 1935*b*, p. 564.

GENOLECTOTYPE.—Chosen Lang and Smith *loc. cit.*: *Thamnophyllum stachei* Hornes in Penecke, 1894, p. 594, pl. viii, figs. 1–3, pl. xi, figs. 1–2. *Barrandei* beds (upper part of Lower Devonian) and Couvinian of Graz, Austria.

DIAGNOSIS.—Dendroid Rugosa with typically straight corallites, and increase which is usually parricidal and produces four large marginal offsets which, in their earliest stages, are united by dissepimental tissue occupying the fork formed by the diverging branches. The septa are so dilated in the dissepimentarium that the only loculi are those enclosed by a median series of horse-shoe dissepiments, the trabecular dilatation of the septa being continuous over the surfaces of these dissepiments. In the tabularium the septa are attenuate and do not reach the axis. Typically the tabulae are transverse, flat or slightly domed or saucered, mostly complete, and usually very widely spaced.

RANGE.—Upper part of the Lower Devonian of Austria, Lower Middle Devonian of Austria and France, and possibly Givetian of France.

REMARKS.—The genus differs from *Disphyllum* in the excessive septal dilatation in the dissepimentarium and in the wide spacing of its tabulae. Lang and Smith have considered it wise to regard the group as a separate genus from *Disphyllum,* and their classification is followed herein. From the American Couvinian *Synaptophyllum* Simpson (1900, p. 202) which Lang and Smith (1935*b*, p. 561) consider synonymous with *Disphyllum,* it differs only in growth form and in the absence of carination on the septa. Of the three European species recognized, the genotype has short septa, complete, widely separated tabulae, and dissepiments suppressed by the septal dilatation; *hornesi* Penecke (1894, p. 595, pl. vii, figs. 13, 14; pl. xi, fig. 3) which occurs with *stachei,* differs in having stouter corallites, longer septa, concave and less regular tabulae, and dissepiments which are not entirely masked by stereome; *murchisoni* Penecke (1894, p. 595, pl. vii, figs. 15-17) has long septa which are peripherally strongly dilated and more or less contiguous laterally, crowded tabulae, and dissepiments almost or completely masked by septal dilatation; it occurs in the Lower Devonian of Austria, and specimens from the Givetian of France have been referred to it by Le Maitre (1937, p. 111, pl. vii, figs. 3-5, 11, 12; pl. viii, fig. 7). These, however, may be *Columnaria* cf. *rhenana* Frech.

In *Thamnophyllum,* as Weissermel (1938, p. 67) has remarked, no epitheca has been observed, and the peripheral stereozone is formed entirely by the dilated septa without any circumferential wall of fibres to the interseptal loculi.

THAMNOPHYLLUM RECLINATUM sp. nov.

(Plate XVI, figs. 7, 8.)

HOLOTYPE.—R25186, British Museum (Natural History), London. E. O. Teale Collection, from Griffith's Limestone Quarries, S.W. from Mansfield, Victoria.

DIAGNOSIS.—*Thamnophyllum* with major and minor septa approximately equal in length, with a wide peripheral stereozone of reclined trabeculae, a narrow tabularium, and a series of small horse-shoe dissepiments sometimes supplemented by other steeply inclined globose dissepiments.

DESCRIPTION.—The corallum is dendroid, the corallites being stick-like, from 3 to 5 mm. in diameter, and irregularly spaced, up to 5 mm. apart. No trace of an epitheca is seen on the corallites, the septa projecting outwards as angular ridges. The septa are of two orders, 14 to 16 of each, and the major septa can only with difficulty be distinguished from the minor, both extending about two-thirds of the way to the axis. They are dilated, particularly in the peripheral half of their length, where they are invariably in contact laterally; narrow interseptal loculi appear between the more axial parts. The septa consist of trabeculae arranged in single series, inclined fan-wise, the inclination being at right-angles to that part of the surface of the horse-shoe dissepiment on which they appear to be based; in the peripheral half of the dissepimentarium, outside the horse-shoe dissepiments, this inclination is horizontal. One series of small horse-shoe dissepiments appears in the axial parts of the dissepimentarium; it may be supplemented by an outer series of small, globose, but highly inclined plates. The tabulae are complete or incomplete, supplemented at their margins by smaller plates. They may be flat or sagging, and are rather distant.

REMARKS.—This species resembles *Thamnophyllum mitchellensis* (Etheridge, 1899, p. 30, pl. A, figs. 6, 7, 8, 12; pl. B, fig. 11) from Sandy's Creek on the Mitchell River, Victoria, in the equality in length of the two orders of septa; it differs in the relative width of the dissepimentarium, which is only half the radius of the corallite in *mitchellensis,* in the width of the peripheral stereozone of inclined trabeculae, which is not noticeable in *mitchellensis,* and in the frequent occurrence of more than one series of dissepiments. It differs from all the Austrian species described by Penecke (1894) from the Lower Devonian *barrandei*-beds of Graz, Austria, in having its two orders of septa approximately equal in length. The known range of the genus in Europe is Upper Lower Devonian, and Lower Middle Devonian, and probably the Victorian species are within these age limits.

Genus PRISMATOPHYLLUM Simpson.

Prismatophyllum Simpson, 1900, p. 218.

Prismatophyllum; Lang and Smith 1935*b*, p. 558, q.v. for synonymy.

GENOTYPE.—*Prismatophyllum prisma* Lang and Smith *loc. cit.* (= *Cyathophyllum rugosum* Edwards and Haime *non* Hall. See Lang and Smith *loc. cit.*) Lower Middle Devonian Onondaga ("Jeffersonville") Limestone; Falls of Ohio, etc., U.S.A.

DIAGNOSIS.—Cerioid Rugose corals with septa which may, or may not, reach the axis; tabulae typically differentiated into a horizontally disposed axial series and an axially inclined peri-axial series; and typically numerous, small, globose dissepiments.

RANGE.—*Prismatophyllum* is rare in the Lower Devonian of France, common in the Couvinian of America and the Couvinian and Givetian of Europe, occurs rarely in the Givetian or Frasnian of Western Australia, and is common in the Frasnian of Europe and America. It has been doubtfully recorded from the Middle Devonian of China, and Yü has placed in it specimens believed to come from Lower Carboniferous rocks in China (Yü, 1933, p. 78).

REMARKS.—The cerioid *Prismatophyllum* shows certain differences from the phaceloid *Disphyllum* in the variability of its internal structure. Thus only two types of dissepimentarium are seen—the *goldfussi* type (p. 226) and a type not known in *Disphyllum,* but common in *Phillipsastraea.* A tabularium found in *Prismatophyllum* but not in *Disphyllum* (unless *Pexiphyllum arcuatum* and *ultimum* of Walther, 1928, figs. 24-26, be *Disphyllum*) is the clisioid axial structure. Spindle septa are common in *Prismatophyllum,* but rare in *Disphyllum.*

MORPHOLOGY AND STRATIGRAPHY OF *Prismatophyllum.*—I consider that the following illustrations represent *Prismatophyllum.* The list obviates the necessity to give references in the discussion following.

LOWER DEVONIAN OF FRANCE.

Acervularia namnetensis Barrois, 1889, pl. i, fig. 1.

Acervularia venetensis Barrois, 1889, pl. i, fig. 2.

COUVINIAN OF AMERICA.

Prismatophyllum anna (Whitfield); Stewart, 1938, pl. 9, figs. 11, 12.

Prismatophyllum prisma Lang and Smith; Stewart, *id.,* figs. 13–15.

Prismatophyllum whitfieldi Stewart (*non* Webster and Fenton), *id.,* pl. 10, figs. 3–4. ? = *Prismatophyllum rugosum* Simpson, 1900, figs. 44, 45; *non* Hall, *non* Edwards and Haime. ? = *Prismatophyllum goldfussi* (Edwards and Haime); Ma, 1937, pl. iii, fig. 2.

Prismatophyllum truncatum Stewart, 1938, pl. 10, figs. 1, 2.

Prismatophyllum kirki Stumm, 1937, pl. 55, fig. 7.

Prismatophyllum sedgwicki (Edwards and Haime); Ma, 1837, pl. iii, fig. 3 (Middle Devonian).

GIVETIAN OF EUROPE.

Prismatophyllum quadrigeminum (Goldfuss); Lang and Smith, 1935*a*, pl. xii, figs. 5, 6.

Prismatophyllum hexagonum (Goldfuss); Lang and Smith, 1935*a*, p. 432.

Cyathophyllum hexagonum Goldfuss; Frech, 1886, pl. iii, figs. 20–22.

Campophyllum dianthus (Goldfuss); Ma, 1937, pl. iv. (Middle Devonian).

Also, *Columnaria sulcata* Goldfuss, Lang and Smith, 1935*a*, pl. xii, figs. 1, 2, seems to me a possible Disphyllid (see p. 241).

GIVETIAN OR FRASNIAN OF WESTERN AUSTRALIA.

Prismatophyllum brevilamellatum Hill, 1936*b*, p. 32, figs. 6–8.

FRASNIAN OF EUROPE.

Cyathophyllum davidsoni Edwards and Haime, 1851, topotype, U. of Qld.

Cyathophyllum boloniense Edwards and Haime, 1851, topotype, U. of Qld.

Prismatophyllum quadrigeminum (Goldfuss); Ma, 1937, pl. iii, fig. 1.

Phillipsastraea pentagona (Goldfuss); Frech, pl. iii, fig. 7.

Phillipsastraea pentagona var. *micrommata* (Roemer); Frech, 1885, pl. iii, figs. 11–13.

Phillipsastraea ananas (Goldfuss); Frech, 1885, pl. iii, fig. 14.

Haplothecia filata Frech, 1885, pl. iv, fig. 7.

Heliophyllum troscheli (Edwards and Haime); Schlüter, 1881, pl. iv, figs. 3, 4.

Heliophyllum cf. *limitatum* (Edwards and Haime); Schlüter, 1881, pl. iv, figs. 1, 2.

FRASNIAN OF AMERICA.

Specimens referred to five species of *Acervularia* Schweigger by Fenton and Fenton, 1924, p. 55, probably are *Prismatophyllum*, but only externals are figured.

The Types of Septa observed in *Prismatophyllum* are:—

1. In the list given above, the French Lower Devonian *namnetensis* and *venetensis*, the European Middle Devonian *hexagonum*, Frech, and Frasnian *pentagonum* and *micrommatum*, *troscheli* and *limitatum* show spindle septa well developed. In spindle septa, dilatation is great towards the inner edge of the dissepimentarium, but lessens towards both axis and periphery. Septa which are not thus dilated may occur in the same corallum.

2. In the American Couvinian and the German Frasnian, the septa have trabecular carinae, opposite or alternate on either side of the septa. The carinae are developed on thick, thin, or spindle septa.

3. In the American Eifelian, the German Givetian, and the French Frasnian, attenuate septa are common; they may be slightly spindled.

4. In the Australian *stevensi* (*vide* infra), the septa are dilated at the periphery and in the dissepimentarium, but attenuate rapidly towards the axis. This is the *Disphyllum depressum* type (see p. 226).

Species with septa not extending beyond the dissepimentarium and species with septa reaching to the axis occur in Lower, Middle and Upper Devonian.

The Tabularium of *Prismatophyllum.*

1. Clisioid; in the American Middle Devonian *sedgwicki* Ma, the tabular floor is domed; and the tabulae are replaced by tabellae; in the German Frasnian *ananas* the tabellae are distinctly grouped in two series, the inner forming a steep dome.

2. In the German Middle Devonian *quadrigeminum* Goldfuss, the French Frasnian *quadrigeminum* Ma, and in the German Frasnian *troscheli* Schlüter, the *Disphyllum minus* type of tabularium occurs with the *goldfussi* type (see p. 225).

3. In the French Lower Devonian *namnetensis,* the American Couvinian *whitfieldi* and the German Frasnian *pentagonum* (Frech) and var. *micrommata* (Frech), and *filatum,* the *Disphyllum geinitzi* type of tabularium (see p. 225) is interrupted by long septa.

4. In the German Middle Devonian *hexagonum* Frech and *dianthus* Ma and the American Couvinian *anna, prisma* and *truncatum,* the *Disphyllum elongatum* type occurs (see p. 225).

The Dissepimentarium is of two types:—

1. In the German Frasnian *troscheli, ananas* and *micrommatum,* there is a change in the direction of inclination of the dissepiments and septal trabeculae near the inner edge of the dissepimentarium. The dissepiments, which are somewhat less globose than in *Disphyllum,* are horizontally based at this critical area, and are inclined on either side. This condition is common in *Phillipsastraea,* but is not yet known in *Disphyllum.*

2. In all other *Prismatophyllum* listed above the dissepiments are inclined towards the axis, the angle of inclination being slight in peripheral series, but increasing in the inner series.

PRISMATOPHYLLUM STEVENSI (Chapman).

(Plate XIII, figs. 6, 7.)

Spongophyllum stevensi Chapman, 1925, p. 113, pl. xiv., figs. 17*a, b;* pl. xv, figs. 24, 27; Mitchell's Quarry, Cave Hill, Lilydale.

Spongophyllum stevensi; Jones, 1932, p. 52.

HOLOTYPE.—13305, National Museum, Melbourne, L. E. Stevens Collection. A portion of the holotype (the only specimen known) is in the collection of the Geological Department of the University of Melbourne, No. 797. Slides cut from this portion are here figured.

Diagnosis.—*Prismatophyllum* with septa dilated in the dissepimentarium and attenuate in the tabularium, with dissepiments globose distally, and two series of dissepiments forming a concave tabular floor.

Description.—The corallum is cerioid and large, with a diameter of 18.7 cm., and a height of 6.8 cm. The corallites are polygonal, usually pentagonal, subequal and straight, with an average diameter of 6 mm. The septa are usually so dilated in the dissepimentarium as to be in contact laterally, but spaces may be left wherein dissepiments are developed. Usually there are 16 major septa alternating with 16 minor septa. The minor septa extend to the inner edge of the dissepimentarium, that is, one-quarter to one-third of the way to the axis. The major septa are unequal in length. Some few of them extend to the axis, but others are very little longer than the minor septa. Those portions of both orders of septa projecting into the tabularium thin rapidly towards the axis. Neither order of septa are waved or carinate, nor do they twist at the axis. The tabulae are typically of two series, an axial series of flat or sagging plates, and an outer series of smaller, inclined plates. Occasionally, however, only one series is present, one or two flat tabulae extending completely across the tabularium. There are one, two, or three vertical series of dissepiments, small, fine, globose distally, and inclined towards the axis.

Remarks.—In its internal structure this cerioid species resembles very closely the phaceloid *Disphyllum depressum* (Hinde; Hill, 1936, pl. i, figs. 4-8) from the Givetian or Frasnian of Western Australia. It cannot be closely compared with any other *Prismatophyllum* and so does not indicate any particular period, but the known range of the genus is Devonian and possibly Lower Carboniferous. Its septa are like the septa of *D. depressum*. Its dissepiments are those characteristic of the genus, the outer peripheral series being larger and more horizontally based than the others, as in *D. goldfussi*. Its tabularium is divided into an inner and an outer series, like that of *D. panicum*.

The species can thus be removed to the Family Disphyllidae, as it possesses all the salient features of that group, as these were described recently by Lang and Smith (1935*b*). It resembles *Spongophyllum*, however, in having concave tabulae, but in the Spongophyllidae the concave tabulae are parallel and close together, whereas in *stevensi* the tabularium has the lack of parallelism characteristic of the *D. panicum* type (see p. 225).

Prismatophyllum chalkii (Chapman).

(Plate XIII, figs. 1–5.)

Acervularia chalkii Chapman, 1931, p. 94, text-fig. Cave Hill, Lilydale, Victoria. Lower or Middle Devonian.

Holotype.—Specimen in Mr. Chapman's Collection, Melbourne.

DIAGNOSIS.—*Prismatophyllum* with slightly carinate septa dilated towards the inner edge of the dissepimentarium; the major septa are withdrawn from the axis; the calical floor rises from the periphery to the inner edge of the dissepimentarium; the tabulae are distant, and complete, and slightly domed or saucered plates are mixed indiscriminately with incomplete plates inclined towards the axis.

DESCRIPTION.—The corallum is cerioid, increase being intermural, the offsets often arising in a ring round the parent, both at the angles and along the sides. The divisional walls between the calices are rather thin in the holotype, with a tendency to zig-zag, as in semi-astraeoid coralla, but are of fair thickness in some fragments (F 3254–5, University of Queensland Collection; 1654–5 in Melbourne University Geology Dept. Colln.). No external view of the species has been obtained. The corallites vary very much in size, 8 mm. being the greatest diameter observed; the offsets are 1 mm. in diameter at origin, and at this size the septa are all extremely short, forming a mere fringe, rather ragged, round the offset, which consists therefore mostly of tabularium; no dissepiments are observed in the offsets when they first arise, but they appear as the diameter increases; at first the septa are equally dilated from epitheca to tabularium, but at greater diameters the peripheral parts are thinner. In the adult coralite (6–8 mm. in diameter) there are 26–30 septa, usually 28. They are all spindle shaped in transverse section, because of their attenuation towards the periphery and again towards the axis; their thickest part is just outside the inner edge of the dissepimentarium; they are usually carinate and therefore are wavy in transverse section, the carinae being directed at right angles to the inclination of the dissepiments like the trabeculae, which have an area of divergence near the inner edge of the dissepimentarium; to the outside of this the trabeculae are inclined upwards and outwards, and to the inside they are inclined upwards and inwards. This condition is well seen in Frech's figure (1885, pl. iii, fig. 14) of *Phillipsastraea ananas* Goldfuss. In some parts of the holotype, however, the septa are thin; the minor septa are usually a little thinner than the major septa. The major septa may proceed into the tabularium, sometimes almost to the axis, as very thin wavy extensions, but in most corallites they are only as long as the minor septa. The dissepiments are very fine, globose plates; most of them are inclined towards the periphery, but near the inner edge of the dissepimentarium they are horizontally based, giving a series like horse-shoe dissepiments but not so globose, and inside this they are inclined towards the axis. In transverse section those plates inclined towards the periphery have their concavity outwards, and frequently they are geniculate; a herring-bone pattern may be produced by the inosculation of two series of dissepiments in each interseptal loculus, one dependent on each of

the bounding septa. The innermost series of dissepiments may be dilated; but whether this dilatation is composed of trabecular extensions from the septa as in *Phacellophyllum* or by a thickening of the horizontal tissue cannot be determined from the material I have. The tabulae are distant and irregular; some are complete, horizontal or slighty saucered; others are incomplete and are inclined towards the axis.

Remarks.—This species has the structure of those Devonian species placed in *Acervularia* Schweigger by Edwards and Haime (1851); the differences between the Silurian and Devonian species of Edwards and Haime's interpretation were first recognized by Simpson (1900, p. 218) who founded *Prismatophyllum* for the Devonian species, but were not generally accepted until Lang and Smith's work on both genotypes was published (1927, p. 451; 1935*b*, p. 558).

This is the only known species of *Prismatophyllum* in which short major septa are combined with an area of divergence in the inclination of the dissepiments and trabeculae. Other species with major septa which do not extend into the tabularium are the Lower Devonian *venetensis,* the American Couvinian *anna, truncatum,* and *kirki,* the Givetian or Frasnian *brevilamellatum,* and the Frasnian *limitatum* E. & H., Schlüter (1881, pl. iv, figs. 1, 2). Other species with an area of divergence of dissepiments and trabeculae are "*Philipsastraea ananas* G." Frech (1885, pl. iii, fig. 14), and *Prismatophyllum approximans* (Chapman, 1914, pl. xlvii) from Victoria.

It is not possible to compare *P. chalkii* closely with any other species of *Prismatophyllum,* and therefore the only assistance it gives in indicating the age of the Lilydale limestone is that the genus is known elsewhere only in the Devonian.

Genus TRAPEZOPHYLLUM Etheridge.

Trapezophyllum Etheridge, 1899, p. 32.

Genotype (by designation): *Cyathophyllum elegantulum* Dun, 1898, p. 85, pl. iii, figs. 5, 6. Limestone Quarry, Loyola.

Diagnosis.—Cerioid Rugose corals with an outer series of flat dissepiments, an inner series of horse-shoe dissepiments, and complete, concave tabulae.

Remarks.—A frequent development in the phaceloid members of the Disphyllidae is the arrangement of the dissepiments into an outer single series of flat plates, and an inner single series of horse-shoe dissepiments. The cerioid members are so far without such a representative in Europe or America, and it is therefore of interest that the Victorian species *Cyathophyllum elegantulum* is such a cerioid form. The phaceloid species showing these characteristic dissepiments are grouped by Lang and Smith into a genomorph of *Disphyllum* {*Phacellophyllum*} Gürich. It may be that the Australian *C. elegantulum* should be regarded as a

genomorph of the cerioid *Prismatophyllum*; but until more evidence of its phylogeny is obtained it is best referred to the genus *Trapezophyllum.* Etheridge made the species the type of a new section of the genus *Cyathophyllum* characterized by the equality and shortness of the septa. But the work of Lang and Smith indicates that its relations are with the *Disphyllum* group; hence the character of the dissepiments is more important diagnostically than the length of the septa. The genus is known only from Loyola, although Etheridge suggested that *C. pelagicum* Billings (1862, p. 108) and *C. wahlenbergii* Billings (*id.*) from the Silurian of Canada should be placed under *Trapezophyllum. C. wahlenbergii* seems from the figures (Lambe, 1901, pl. xi, fig. 2) to be *Xylodes rugosus. C. pelagicum* is unfigured.

TRAPEZOPHYLLUM ELEGANTULUM (Dun).

(Plate XVI, figs. 9–11.)

Cyathophyllum elegantulum Dun, 1898, p. 85, pl. iii, figs. 5, 6.

Cyathophyllum ? elegantulum; Etheridge, 1899, p. 31, pl. B, figs. 2–4. Sections figured 3, 4, are A.M.2 in Australian Museum.

C. (*Trapezophyllum*) *elegantulum;* Etheridge, 1899, p. 32.

HOLOTYPE.—41717, Collection of the Geological Survey of Victoria, formerly part of 107, George Sweet Collection. Limestone Quarry, Loyola. Figured Dun *loc. cit.*, Etheridge *loc. cit.*

DIAGNOSIS.—*Trapezophyllum* with major and minor septa equal and extending half-way to the axis.

DESCRIPTION.—The corallum is cerioid, of unknown shape. Increase is intermural, but sometimes the offsets are not separated from the parent corallites by epitheca, and the corallum is thus locally thamnastraeoid. The corallites are usually hexagonal, with a diameter between 2 and 4 mm. There are 10 to 12 major septa alternating with minor septa, but the minor septa are only with difficulty distinguished from the major septa, both series extending half-way to the axis. They are thin and do not show carinae, but their axial ends are dilated and rarely in contact. Occasionally very short tertiary septa are seen. The dissepiments are arranged in two series; an inner single series of small horse-shoe dissepiments is regularly developed between the axial ends of the septa, and the outer development is usually of a single series of plates transverse or slightly inclined to the periphery, rather fewer than the horse-shoe dissepiments, but there may be two columns of plates which in vertical section are flattened on top and bulge towards the axis, a number giving the appearance of superposed rhombs. The tabulae are complete, and flat or sagging, about 5 in the space of 5 mm.

REMARKS.—The sporadic occurrence of tertiary septa is unusual. No comparable cerioid species is known. The phaceloid *Disphyllum* {*Phacellophyllum*} has a similar dissepimentarium,

but the tabularium and septa of *Trapezophyllum elegantulum* are distinctive. *Phacellophyllum* occurs in the European Lower Devonian, Givetian and Frasnian.

Genus PHILLIPSASTRAEA d'Orbigny.

Phillipsastraea d'Orbigny, 1849, p. 12.

Phillipsastraea; Lang and Smith, 1935*b*, p. 556, q.v. for synonymy.

GENOTYPE.—*Astraea Hennahii* Lonsdale, 1840, p. 697, pl. lviii, figs. 3, 3*b* (see Lang and Smith *loc. cit.*). Upper Devonian, Barton Quarry, Newton, Plymouth.

DIAGNOSIS.—Plocoid Rugose corals; typically the septa are dilated at the margin of the tabularium, and are usually carinate; there is no columella, and the tabulae are horizontal, complete or incomplete; dissepiments are numerous, small and rather globose, and those at the inner edge of the dissepimentarium may be horse-shoe shaped.

REMARKS.—Plocoid corals occur commonly in the Devonian, and those which show the characters of the Disphyllidae—globose dissepiments frequently divided into more than one series, septa which are carinate with trabecular carinae, spindled, or dilated in the dissepimentarium, and tabulae typically of two series—may be placed in the genus *Phillipsastraea,* in conformity with Lang and Smith's division of the Disphyllidae into genera primarily according to the form of the corallum.

The oldest species which has been placed in *Phillipsastraca* is *walli* Etheridge (1892, p. 169, pl. xi, fig. 7) from the Lower Ludlow of New South Wales. This is plocoid, but its dissepiments are not so globose as in typical Disphyllidae, nor are its tabulae, which are deeply concave, differentiated into two series, and its septa show none of the modifications of the Disphyllidae. It may be that this species is not a member of the Disphyllidae at all, and should therefore be moved from *Phillipsastraea.* It differs from *Arachnophyllum,* the Silurian plocoid genus, in having neither the septal modification nor the axial structure of that genus, and in having parallel, deeply concave, complete tabulae. No figures of the fine structure of *P. silurica* Lahusen are available, but Weissermel (1894, p. 611) considered it a true Silurian *Phillipsastraea.*

No figures of the fine structure of the Bohemian Lower Devonian *P. cuncta* Počta (1902, pl. 113, fig. 18) are available, and the plocoid form from the Lower(?) Devonian of Ellesmere-land referred to *P. gigas* Billings by Loewe (1914, p. 14, pl. iv, fig. 2) is insufficiently figured.

Stumm (1937) has considered the Eifelian plocoid species of Nevada to be separable from *Phillipsastraea,* and has placed them in *Radiastraea* Stumm (1937, p. 439) and *Billingsastraea* Grabau. Leowe (1914) considered three species from the Middle Devonian

of Arctic America to be *Phillipsastraea,* but his figures are insufficient. No *Phillipsastraea* has been recorded as such from the Middle Devonian of Europe, but *Keriophyllum astraeiforme* Sochkina (1936, p. 63, figs. 71-72) from the Northern Urals may be one.

From the Upper Devonian comes the type *P. hennahii,* a form with spindle septa, a dissepimentarium in which there is an area of divergence in the inclination of the plates near the inner boundary, and a tabularium of the *Disphyllum goldfussi* type (see p. 225). *P. boloniense* (see Lang and Smith 1935*b*, p. 556, text-figs. 12-13) has similar septa, but the dissepiments are horizontally based near the periphery, and steeply inclined at the inner edge of the dissepimentarium. The tabulae are of the *Thamnophyllum* type. *P. delicatula* Hill (1936, p. 30, text-figs. 4, 5) from Western Australia has unthickened septa, but dissepiments and tabulae as in *boloniense.* The Upper Devonian of Europe and America has a second group of Phillipsastraeids commonly but wrongly called *Pachyphyllum* (see Lang and Smith, 1935*b*, p. 555), such as *devoniense* (Edwards and Haime, 1852, p. 397), *bouchardi* (Edwards and Haime, 1851, pl. 7, fig. 7), *ibergense* (Roemer, 1855, pl. vi (xxi), fig. 24), *johanni* (Hall and Whitfield; Fenton and Fenton, 1924, pl. xv, figs. 6, 7), *woodmani* (White; Fenton and Fenton, 1924, pl. vii, figs. 1-3) etc. This second group is known so far only from the Upper Devonian, and is characterized by the excessive dilatation of the septa near the inner margin of the dissepimentarium.

The only record of a *Phillipsastraea* from Asia is that of "*Smithia hennahi*" in Deprat and Mansuy, 1912 (*fide* Yabe and Hayasaka 1920, p. 101) from the Couvinian of Yun-nan.

RANGE.—Upper Devonian of Europe, America and Western Australia. Doubtfully from the Upper Silurian of New South Wales and the Baltic states, from the Lower Devonian of Bohemia, and from the Middle Devonian of Europe and Arctic America.

PHILLIPSASTRAEA SPECIOSA Chapman.

(Plate XVI, figs. 1–4.)

Phillipsastraea speciosa Chapman, 1914, p. 306, pl. xlix, figs. 10, 11; Plate I, figs. 12–14. Griffith's Quarry, Loyola, near Mansfield.

HOLOTYPE.—2487, W. H. Ferguson Collection, Geological Survey of Victoria, and two slides cut from it, here figured, 1387 and 1388, National Museum, Melbourne.

DIAGNOSIS.—Astraeoid *Philipsastraea* with spindle septa sometimes extending to the axis as thin plates or as discontinuous trabeculae, or projecting just within the tabularium; with the

greatest height of the floor of the dissepimentarium at its inner border, the outer dissepiments being inclined towards the periphery; and with concave tabulae.

DESCRIPTION.—The corallum is astraeoid and spreading, the greatest thickness observed being 24 mm. The corallites are 4 to 6 mm. wide, irregularly pentagonal and not bounded by an epitheca, their margins being defined by lines along which the septa are turned aside to meet those of neighbouring corallites at an angle. The tabularia are about 2 mm. in diameter, and from 4 to 7 mm. apart. The stereozone is narrow, at the inner edge of the dissepimentarium. There are from 26 to 30 septa, alternately major and minor. They are dilated so as to be in contact or almost so at the inner edge of the dissepimentarium, but the dilatation decreases very gradually outwards. They never become attenuate, and in some cases may be carinate. The carinae are extensions from the trabeculae, and may be opposite or sub-opposite, when the septum appears zig-zag in transverse section. The trabeculae are more or less distinct, and have an area of divergence near the inner border of the dissepimentarium. The minor septa end rather bluntly just inside the tabularium, but the major septa sometimes extend to the axis, thinning very gradually as they do so, or being represented by discontinuous trabeculae; or they may be very little longer than the minor septa. The tabulae are shallowy concave, usually complete, and they may be supplemented at the margin of the tabularium by small inclined tabellae. In some corallites when the septa are very long, the tabulae are domed. The dissepiments are globose and very small, and frequently do not extend completely across the interseptal loculi, but inosculate with one another. The innermost series is more globose and projects higher than the rest of the tissue; they are almost horse-shoe dissepiments. The others are disposed horizontally or inclined towards the periphery.

REMARKS.—The species is close to the species-group of the genotype from the Upper Devonian of Europe. In the manner of its septal dilatation, and the size of the corallites, it is closest to the form figured by Edwards and Haime (1853, pl. 54, fig. 4) but the variation in the development of the septa within the dissepimentarium distinguishes it; the discontinuous trabeculae are not seen in *hennahii,* to my knowledge.

Corallites in which the major septa are short closely resemble those of *P. currani* Etheridge (1892, pl. xi, figs. 1–6) from Fernbrook, New South Wales, except that they are smaller.

PHILLIPSASTRAEA sp. indet.

(Plate XVI, figs. 5, 6.)

Phillipsastraea walli Etheridge; Chapman, 1914, p. 305, pl. xlviii, figs. 7–9, Loyola; *non Phillipsastraea walli* Etheridge, 1892, p. 169, pl. xi, fig. 7, Upper Silurian, Yass, New South Wales.

MATERIAL.—Two slides, 1374 and 1375 (figured *mihi,* and Chapman *loc. cit.*), National Museum, Melbourne, cut from specimen 2491, whose whereabouts are unknown; and three slides cut from specimen 2489, W. H. Ferguson Collection, Geological Survey Museum, Melbourne, Victoria. All from Griffith's Quarry, Loyola, near Mansfield.

DESCRIPTION.—The corallum is thamnastraeoid or in part astraeoid; the tabularia are 1.5 to 2 mm. in diameter, and 3 to 6 mm. apart. There are 22 to 24 septa, half of which extend further towards the axis than the others (the minor septa), which project only very slightly into the tabularium. The septa are all thin, with short, sharp irregular waves, and are continuous throughout the dissepimentarium, not being broken up by the dissepiments. The dissepiments are small, crowded, and frequently geniculate. Their reverse curvature in the peripheral parts of the dissepimentarium suggests that there is an area of divegence in their inclination, as in *speciosa.* An inconclusive vertical section shows distant, horizontal, complete tabulae.

REMARKS.—The New South Wales Upper Silurian *walli* Etheridge is distinguished by the discontinuity of the septa in the outer parts of the dissepimentarium, by the marked radiality of arrangement of the septa in a wreath round the tabularium, and by the deep almost parallel-sided concavity of the tabulae; Loyola specimens show none of these three characters, and I think that the equation of the Loyola specimens to *walli* cannot be sustained, in spite of the general similarity in size of corallite and number of septa. On the other hand the specimens show some similarity to *speciosa,* with which they occur, but not the spindle septa believed to be characteristic of *speciosa.* More material is necessary for a safe determination of the species.

Genus LOYOLOPHYLLUM Chapman.

Loyolophyllum Chapman, 1914, p. 306; proposed as sub-genus of *Columnaria* Goldfuss, 1826 (=*Favistella* Hall, 1847); by a typographical error the name is spelt *Loyolophyllia* on p. 301.

GENOTYPE, by monotypy: *Columnaria* (*Loyolophyllum*) *cresswelli* Chapman, 1914, p. 306, pl. li, figs. 15, 16; pl. lii, figs. 17, 18. Griffith's Quarry, Loyola, near Mansfield.

DIAGNOSIS.—Cerioid corals with small corallites, thin septa, complete, horizontal or saucered tabulae, and sporadically an incomplete series of vertically elongate dissepiments lining the wall in the interseptal loculi.

RANGE.—The genus is known only from the type locality.

REMARKS.—Chapman observed that this form was very similar in structure to *Columnaria* of the *alveolata* morphology, and regarded it as a sub-genus of *Columnaria,* from which it differed by the tabulae being saucered rather than domed, and by the

presence of dissepiments. Like Etheridge (1918, p. 53), I consider these distinctions, particularly the presence of dissepiments, to be generic in value, and, like Chapman, I consider the genus to be related to *Columnaria alveolata,* i.e. to *Favistella* Hall. There is, however, some doubt whether the family should be called Columnariidae or Favistellidae, and for this reason I have departed from the orthodox method of reviewing the family before the genus. The family and the difficulties in its nomenclature are discussed in the following remarks on *Favistella* and similar genera:—

There are in the Ordovician, Silurian and Devonian a number of compound corals whose structure is very simple—major and very short minor septa, and tabulae, without mural pores. Goldfuss (1826) founded the genus *Columnaria* for such forms, his syntypes being *alveolata* from the Ordovician of North America (a species later described as *Favistella stellata* by Hall, 1847), *laevis* from the ? Jurassic of Italy, and *sulcata* from the Devonian of Prussia. The first of these has no dissepiments; but the third, which was chosen by M'Coy (1849, p. 121) as the genolectotype, has. Most authors have, however, followed Edwards and Haime's later (1851, p. 308) and therefore invalid selection of *C. alveolata* as type, and have interpreted *Columnaria* as synonymous with *Favistella* Hall.

Frech (1891, *fide* Weissermel, 1897, p. 867) considered the genus *Cyathophylloides* Dybowski (1873, p. 379), with genosyntypes *kassariensis* Dybowski, *fasciculus* Kutorga and *irregularis* Dybowski, as a synonym of *Columnaria;* and indeed Weissermel's figures (1897, p. 871) of *kassariensis,* which Lang and Smith (1935*b*, p. 543) chose as genotype of *Cyathophylloides,* show a generic similarity to *Columnaria alveolata,* and *Cyathophylloides* is to be regarded as synonymous with whatever genus takes *alveolata.*

Weissermel (1897) recognized four compound species and two solitary species, all with thick walls and without dissepiments, as a sub-genus of *Columnaria* (which he appears to have interpreted on *alveolata*). These species were: the phaceloid *Densiphyllum tamnodes* Dybowski from the Ordovician of Estland, the cerioid *Cyathophylloides* (*Densiphyllum*) *contorta* Weissermel (1894, pl. 1, fig. 2) from the Ordovician or Silurian of Europe, the cerioid *Columnaria devonica* Schlüter (1889, p. 272) and the phaceloid *Columnaria rhenana* Frech (1886, pl. iii, fig. 19) from the Devonian of Germany, and the solitary *Densiphyllum thomsoni* Dybowski and *Densiphyllum rhizobolon* Dybowski, both from the Ordovician of Estland. Weissermel named the genus *Pycnophyllum* Dybowski, *Pycnophyllum* being a correction for *Densiphyllum* Dybowski, made (*fide* Weissermel, 1897, p. 867, footnote) by its author. But by Article 19 of the Rules of Zoological Nomenclature, the original orthography of

a name is to be preserved unless an error of transcription, a *lapsus calami*, or a typographical error is evident, so that *Densiphyllum* must be retained for Dybowski's genus. No type has ever been chosen for *Densiphyllum*, and until good sections of Dybowski's syntypes have been illustrated, critical remarks on the extent and relations of the genus are without value.

Lang and Smith (1935*a*) studied Goldfuss' specimens of *alveolata* and *sulcata*, and concluded that they were congeneric. But this conclusion I doubt, from the evidence of the published figures. The vertical sections which they figure from the type of *sulcata* show dissepiments, very similar to, but perhaps less globose than, those of *Disphyllum geinitzi* figured by the same authors (compare L. and S. 1935*b*, pl. xxxvi, fig. 3, with L. and S., 1935*a*, pl. xii, fig. 2, which is inverted). And it seems to me that *sulcata* might easily be a cerioid member of the Disphyllidae, with the internal structure closely similar to that of *D. geinitzi.*

Should a re-study of the type material confirm my opinion, then *Columnaria* would have to be applied only to such cerioid Disphyllidae, and not to species like the Ordovician *alveolata,* which have no dissepiments. For the latter, Hall's name *Favistella* would need to be revived, and *Cyathophylloides* Dybowski regarded as synonymous with it, and not with *Columnaria.*

Lang and Smith (1935*b*, p. 548) have considered *Fasciphyllum* Schlüter (1885, p. 52, genotype, by designation, "*Fascicularia?*" *conglomerata* Schlüter, 1880, p. 147 from the Givetian of the Eifel) to be a synonym of *Columnaria* (genotype *sulcata*). *Conglomeratum,* however, possesses a single series of vertically elongate dissepiments like those found in *Loyolophyllum;* i.e., they are dependent on the wall in the interseptal loculi, and are unlike those of *sulcata.* No dissepiments occur in *alveolata,* and I cannot accept that *conglomeratum* is congeneric with either *sulcata* or *alveolata,* but consider that palaeontological comparisons will probably be more exact and stratigraphical correlation made easier by regarding these three species as belonging to different genera, thus: *Columnaria sulcata, Favistella alveolata,* and *Fasciphyllum conglomeratum.*

In summary, a study of the published figures leads me to the view that the species we have been considering are best grouped as follows:—

Family DISPHYLLIDAE.—The Middle Devonian cerioid *Columnaria sulcata* Goldfuss, *Columnaria arctica* (Loewe, 1914, pl. ii, fig. 3, Ellesmereland).

Family FAVISTELLIDAE.—*Favistella alveolata* (Goldfuss = *F. stellata* Hall), cerioid, from the American Ordovician; *Favistella calicina* (Nicholson, 1874; 1879, pl. x, fig. 2), phacelo-cerioid, American Ordovician; *Favistella fascicula* (Kutorga,

Weissermel), phaceloid, Ordovician of the Baltic States; *Favistella kassariensis* (Dybowski, Weissermel), cerioid, Silurian of the Baltic States; *Favistella gothlandica* (Edwards and Haime, 1851, pl. 14, fig. 2), cerioid, Silurian of Gotland; *Favistella pauciseptata* (Etheridge, 1897, pl. viii), cerioid, Silurian of New South Wales; *Favistella neminghensis* (Etheridge, 1918, pl. ix), cerioid, Devonian of New South Wales; *Favistella symbiotica* (Charlesworth, 1914, pl. xxxi, fig. 2), phaceloid, Lower Devonian, Eastern Alps; *Fasciphyllum conglomeratum* (Schlüter, phaceloid, Middle Devonian of Germany), ?, = *Cyathophyllum syringoporoides* Charlesworth (1914, pl. xxxi, fig. 1, Lower Devonian, Eastern Alps); *Loyolophyllum cresswelli* Chapman, cerioid, Lower Devonian, Victoria.

In all probability some of the species placed by Weissermel in the sub-genus *Densiphyllum* (see p. 240), are members of the Favistellidae.

Thus in the author's opinion *Loyolophyllum* is a member of the Favistellidae. Its closest relative is *Fasciphyllum* Schlüter from the Lower Devonian of the Eastern Alps and the Middle Devonian of Germany. It is cerioid, whereas *Fasciphyllum* is phaceloid. These dissepimented Favistellids differ from *Spongophyllum kunthi* Schlüter (1880; 1881, pl. viii, figs. 1, 2, Couvinian, Germany) and related forms in that the dissepiments do not break through the septa but occupy the loculi between them, whereas in *kunthi* the dissepiments are lonsdaleoid, and the septa are withdrawn from the periphery.

Loyolophyllum cresswelli Chapman.

(Plate XV, figs. 8–11.)

Columnaria (Loyolophyllum) cresswelli Chapman, 1914, pp. 306–8, pl. li, figs. 15–16; pl. lii, figs. 17–18. Griffith's Quarry, Loyola.

Loyolophyllum cresswelli; Etheridge, 1918, p. 51.

Holotype.—12904, and 5 paratypes (12905–9). A. W. Cresswell's Collection, National Museum, Melbourne.

Diagnosis.—As for genus.

Description.—The corallum is cerioid, mushroom shaped, expanding very rapidly from an apex, attaining a diameter of 10 cm. Increase is intermural. The corallites are usually hexagonal, with average diameter 2 mm., though they are only 1.13 mm. in the type. There are 10 septa, continuous at their bases with a very narrow peripheral stereozone, about 0.25 mm. thick. The major septa are unequal in length; four to six may extend almost to the axis, as in *Stauria*. The minor septa may be one-third as long as the major septa. The septa show no carinae; some sections suggest that they are acanthine, but the material is very badly preserved. Development of the elongated dissepiments is variable; it may be limited to a few scattered

plates adhering to the epitheca by their upper and lower edges; or the lower edge of one plate may rest on the upper part of an earlier dissepiment; or one complete vertical series may be formed. The tabulae are complete, usually sagging, sometimes horizontal, about 10 in the space of 1 cm.

REMARKS.—This cerioid species has a similar internal structure to the phaceloid *Fasciphyllum conglomeratum* (Schlüter) from the Middle Devonian of Germany and *Fasciphyllum syringoporoides* (Charlesworth) from the Lower Devonian of the Eastern Alps, as already mentioned in the remarks on the genus.

ZOANTHARIA RUGOSA INCERTAE SEDIS.

Genus LYRIELASMA nov.

(Lurion = a lyre, elasma = a plate; from the fanciful resemblance of the septa to the strings of a lyre.)

GENOTYPE.—*Cyathophyllum subcaespitosum* Chapman, 1925, p. 112, pl. xiii., figs. 15, 16*a*, *b*. Cave Hill, Lilydale.

DIAGNOSIS.—Fasciculate Rugosa with the major septa directed towards the median plane, with wide, deeply concave incomplete tabulae, and with a peripheral stereozone of irregular width, formed by the dilatation of major and minor septa in the dissepimentarium.

RANGE.—The genus is known with certainty only from the Lower Devonian of Loyola, and the Lower of Middle Devonian of Lilydale, Victoria. Possible species, however, occur in the Lower and Middle Devonian of Europe.

RELATIONS.—*Lyrielasma* shares the arrangement of its septa and the deep concavity of its tabulae with the European Silurian *Cymatelasma* Hill and Butler (1936) and *Spongophylloides* Meyer (see Butler, 1934), and with a large number of German and American Devonian forms. It differs from *Cymatelasma* and *Spongophylloides* in being compound and in the characters of the dissepimentarium. No dissepiments at all have been seen in the peripheral stereozone of *Cymatelasma;* in *Spongophylloides* there is a lonsdaleoid border of very steeply inclined dissepiments. In *Lyrielasma* dissepiments occur fairly frequently within the interseptal loculi in the peripheral stereozone, but usually do not cause the septa to become discontinuous; they are steeply inclined like those of *Spongophylloides*. It does not seem reasonable to place *Lyrielasma* with the Cymatelasmidae. The classification of the Devonian forms into genera and families is not yet satisfactory. Wedekind (1924, 1925) in his study of the Rugosa of the German Couvinian and Givetian, has placed such Givetian corals into the family Stringophyllidae, most of them showing in addition a tendency for the septa to be represented in the dissepimentarium by discontinuous trabeculae. *Lyrielasma* differs

from this group in having the septa continuous and dilated in the dissepimentarium. The Couvinian Digonophyllinae described by Vollbrecht (1926) differ chiefly in the presence of a key-hole fossula in the tabularium.

It is possible that this arrangement of septa and tabulae is a homeomorphic development which is as much characteristic of the Devonian as the axial structure is characteristic of the Carboniferous.

The arrangement and peripheral dilatation of the septa of some forms from the Upper Ludlow of the Urals, placed by Sochkina (1937, pl. xiv, figs. 1-5) in *Omphyma,* recall *Lyrielasma,* but the Russian species have large lonsdaleoid dissepiments and tabulae which are flat rather than concave, and I do not think any close relation is indicated.

Species from the Lower Devonian of the Eastern Alps and the Chalonnes Limestone, and from the Middle Devonian of the Eifel, which might belong to the genus, are discussed in the remarks on the genotype.

Lyrielasma subcaespitosum (Chapman).

(Plate XIV., figs. 1-6, plate XV, figs. 6, 7.)

Cyathophyllum subcaespitosum Chapman, 1925, p. 112, pl. xiii, figs. 15, 16*a, b.* Cave Hill, Lilydale.

Holotype.—1731 and 14065, National Museum, Melbourne.

Diagnosis.—*Lyrielasma* with wide, low, septal carinae, parallel to the distal edges of the septa.

Description.—The corallum is fasciculate, the corallites diverging slightly. The largest fragment of corallum is 75 mm. in diameter and 60 mm. high; the corallites in it are unequally spaced, being in contact or very close immediately after increase, and up to 10 mm. apart later; they have an average diameter of 12 mm., and may be slightly compressed. The epitheca shows faint longitudinal grooves, with broad ribs. Growth annulation is also faintly marked. No calices are available for study.

There are from 24-30 major septa, alternating with an equal number of minor septa, the number increasing as the width of the corallum grows from 8 mm. to 12 mm. The minor septa may be two-thirds as long as the major septa. The septa are dilated and in contact in a peripheral stereozone of variable width; in many corallites it is mostly as wide as the dissepimentarium, and in these the septa are moderately dilated in the tabularium also; but in a few (one in the holotype, and two individuals found isolated—F 1329*a, b,* Australian Museum) it is very narrow, and the septa are almost attenuate. The septa are slightly waved, the crests of the waves running along the sides of the septum, parallel to its upper edge; sometimes, particularly when the septa are thin, the crests are angular, and

thin carinae grow out from them. The septa are directed towards a median plane of the tabularium; this plane is probably that of the cardinal and counter septa, but direct proof is lacking. The septum at each end of the plane is usually very short, particularly in the larger corallites; but occasionally, in the smaller corallites, one may be very long, extending to the axis; this long one is presumably the counter-septum. The two or three neighbours of these "directive" septa are usually curved slightly towards the axial ends of the "directive" septa. The remaining septa are not curved, and are unequal. Dissepiments are developed when the dilatation of the septa is not so great as to fill the interseptal loculi; they are equal and steeply inclined as in *Spongophylloides*. Discontinuity of the septa occurs extremely rarely—in one individual in the holotype, the section showed a few scattered lonsdaleoid dissepiments (plate xiv, fig. 1). The tabularium is usually oval, and is just more than one-third the width of the corallite in the direction of the median plane, and just less than one-third this width in the direction at right angles. The tabular floors are inverted cones; the tabellae are wide and shallowly curved, and slope at about 60° towards the axis, about three in the space of 2 mm. The dissepiments, when they are free to develop in the interseptal loculi because the septa are not dilated, are smaller, and more globose, and less steeply inclined than the tabellae.

Occurrence.—Three corallites probably from one corallum have been collected from Griffith's Quarry, Loyola, in the Lower Devonian. They show somewhat greater dilatation than the types from Lilydale, and in all three the counter-septum is very long.

Remarks.—A corallite figured by Charlesworth (1914, pl. xxxi, fig. 8, *non* fig. 7) from the Lower Devonian Reef-limestone of the Eastern Alps is so similar in transverse section to *L. subcaespitosum* that it might have been drawn from the type, but a longitudinal section is needed before generic identity can be proved. Le Maitre has described and figured very similar individuals from the Chalonnes limestone, France, as *Cyathophyllum elongatum* Le Maitre (1934, p. 152, pl. v, figs. 10-12) and *Cyathophyllum dianthus* Goldfuss. She considers the Chalonnes limestone to occupy a horizon transitional between Coblenzian and Couvinian. Specimens (Sedgwick Museum, Cambridge, A 8636, A 9100, and A 9102-3) from the Middle Devonian of the Eifel differ from the Victorian species in the absence of dilatation, in the greater length of the septal carinae, and in the less conspicuous median plane. But close relationship, probably generic, is indicated by the general arrangement of the plates.

In the oval tabularium and the waving of the septa, the Upper Silurian species placed by Sochkina (1937, p. 74, pl. xiv) in *Omphyma* resembles *L. subcaespitosum*, but the horizontal

skeletal elements are very different. Differences from the Silurian *Cymatelasma* and *Spongophylloides* have been sufficiently noticed in the remarks on the genus.

Genus MICTOPHYLLUM Lang and Smith.

Mictophyllum Lang and Smith, 1939, p. 155.

GENOTYPE.—*Mictophyllum nobile* Lang and Smith, *id.*, pl. iv. Upper Devonian (Frasnian), Lower Chute, Redknife River, a tributary of the Mackenzie R., which enters the main stream between Great Slave Lake and Fort Simpson, North-West Canada. Pl. XIII, figs. 8–9.

DIAGNOSIS.—Simple Rugose corals with septa at first dilated in the dissepimentarium and thin in the tabularium, later thinning in the dissepimentarium also; the axial ends of the major septa have an irregular vortical curvature. The tabulae are domed and replaced by tabellae. The dissepiments are geniculate and sometimes dilated, the dilatation being continuous with that of the septa, and are small, rather globose and steeply inclined.

REMARKS.—In the irregular vortical curvature of the axial ends of the septa, the geniculate dissepiments, and the domed, incomplete tabulae, this genus resembles the Australian Upper Silurian Phaulactid *Hercophyllum* Jones (1936, p. 53). But in *Hercophyllum* as in other Phaulactids the septa are never dilated in the dissepimentarium, while in *Mictophyllum* a peripheral stereozone is present in the young stages. I have seen figures of only one European species which may belong to this genus. This is *Cyathophyllum graecense* Penecke (1894, p. 600, pl. viii, figs. 14, 15; pl. xi, figs. 5, 6) from the Coblenzian *Heliolites barrandei*-beds of Graz, Austria. Thus the known range of the genus is Lower Devonian of Europe and Upper Devonian of Canada.

I cannot indicate any genus as being closely related to *Mictophyllum,* and so have not placed it in any family.

MICTOPHYLLUM CRESSWELLI (Chapman).

(Plate XIV, figs. 7–11.)

Cyathophyllum cresswelli Chapman, 1925, p. 111, pl. xiii, figs. 11–14. Cave Hill, Lilydale.

HOLOTYPE.—1267 and 1270 (one corallum cut vertically), National Museum, Melbourne.

DIAGNOSIS.—Sub-cylindrical, erect or slightly curved *Mictophyllum* with long minor septa.

DESCRIPTION.—At first the corallum is patellate and curved (13302, National Museum, Melbourne); later increase in diameter is gradual, and the corallum is sub-cylindrical and erect or but

slightly curved. The largest diameter seen is 34 mm., and the greatest length (fragment only) is 76 mm. There are slight rejuvenescence constrictions in diameter in most corallites. The epitheca shows fine growth annulation, broad, low longitudinal ridges, and narrow longitudinal furrows. The calice is not known.

At 14 mm., the diameter of the smallest cross-section observed, the outer edges of the 32 major septa and 32 minor septa are dilated and in contact in a peripheral stereozone 1.5 mm. wide. The inner part (about 1 mm.) of each minor septum is attenuate, so that the dissepiments, usually curved, sometimes geniculate, develop in the loculi. The axial ends of the major septa are attenuate and extend unequally almost to the axis; the curvature of these ends is irregular and the interseptal loculi are unequal.

At a diameter of 23 mm. (Australian Museum F. 1242), 38 major septa and 38 minor septa are present. The peripheral stereozone is 2 mm. wide, and the length of the unthickened axial parts of the minor septa is 2 mm. The dissepiments between these unthickened parts are thin and usually curved, though sometimes geniculate. The curvature of the axial ends of the major septa is vortical, but irregular due to the different widths of the interseptal loculi.

At the average adult diameter of 28 mm., 35 major septa and 35 minor septa are present, and the fossula is indistinct. The minor septa are slightly thinner than the major septa, and are about two-thirds as long. Dilatation decreases as the height of the corallum increases, and no continuous stereozone is present in the later stages, interseptal loculi separating the septa right to the epitheca; but where there is dilatation, it is continuous from septum to septum across the dissepiments, which are usually geniculate. The attenuate axial ends of the major septa are curved vortically but irregularly, the irregularity being due to the expansion near the axis of some loculi or pairs of loculi, and the consequent crowding of the remaining ends; some of the axial ends are shorter than the others, and in crowded areas may abut on to the longer ones. In the adult stages most of the dissepiments are geniculate in transverse section, but some few are still curved. In the vertical section they are seen to be small, rather globose, and usually steeply inclined. The dissepimentarium is about 8 mm. wide at a diameter of 28 mm., and is equal to the length of the minor septa. The tabulae are usually incomplete, and the tabellae are then thin, small and not highly arched, and the tabular floors are low domes; when the tabulae are complete they are slightly saucered.

Remarks.—The species is known only from Lilydale in Victoria. It is closer to *M. graecense* (Penecke, 1894, p. 600, pl. viii, figs. 14, 15; pl. xi, figs. 5, 6) from the Coblenzian of Graz

than to the Frasnian genotype, for it has well-developed minor septa like *graecense,* whereas in *nobile* the minor septa have disappeared, leaving inosculating dissepiments.

Cystimorphs.

Cystimorphs are Rugose Corals in which the vertical skeletal elements are very much reduced, and the corallum is constructed almost entirely of arched horizontal skeletal elements, none of which extend completely across the lumen. The earliest cystimorphs occur in the Valentian of England (*Cystiphyllum cylindricum* Lonsdale, Smith, 1930, p. 300), Stage 7c α of Norway (*Cystiphyllum signatum* Lindström MS. Scheffen, 1933, pl. vi, figs. 3, 4) and the Clinton of North America (*Cystiphyllum spinulosum* Foerste, 1906, p. 321, pl. v, fig. 1, Bassler, 1915, p. 372). Thereafter cystimorphs, which can arise in many different lineages by the degeneration of the vertical skeletal elements (" cystiphylloid trend " Lang, 1938, p. 150), are common until the Upper Devonian, when only rare examples occur. None are known in the Carboniferous or Permian.

In England, *Cystiphyllum* (genotype *C. siluriense* Lonsdale) continues in the Wenlock and Ludlow (Lang and Smith, 1927, p. 455) ; *Goniophyllum* Edwards and Haime (Lindström, 1882, p. 42), a gonioid cystimorph with septal fragments which are linear and not acanthine, and *Microplasma* Dybowski, a fasciculate cystiphyllid (Lang and Smith, 1927, p. 478) occur in the Wenlock; *Hedströmophyllum* Wedekind (1927, p. 66), a cystiphyllid with very long trabeculae, has been recorded from the Aymestry limestone (Alexander, 1936, p. 106). These four genera also occur in the Middle and Upper Gotlandian of Gotland, with in addition *Araeopoma* Lindström (1882, p. 57), a cystiphyllid with remarkable epithecal trails, *Gyalophyllum* Wedekind (1927, p. 64) a cystiphyllid with a peripheral stereozone of closely packed holacanths in lamellar sclerenchyme, *Rhizophyllum* Lindström (1865; 1882, p. 22), calceoloid cystimorph with septal fragments which are linear and not acanthine, and *Holmophyllum* Wedekind (1927, p. 31), a cystimorph with deeply concave tabulae, and long, discontinuous trabeculae in the wide dissepimentarium of fine dissepiments. The Lower Ludlow (*fide* Lang and Smith, 1927, p. 476) of Tachlowitz in Bohemia contains numerous *Cystiphyllum* (Počta, 1902, p. 164). Cystiphyllids have been recorded from the Niagaran of America (Bassler, 1915, p. 371), and *C. cylindricum* occurs in China (Lindström, 1883, p. 73). *Rhizophyllum* occurs in the Upper Silurian of Australia), Etheridge, 1891, p. 201).

There is considerable diversity in the structure of these Silurian cystimorphs, and they probably belong to more than one family; *Goniophyllum,* for instance, may be related to the Phaulactidae.

Cystiphyllum itself has septa represented by holacanths, set in lamellar sclerenchyme which dilates the horizontal skeletal elements (Hill, 1936*a*, p. 211). It is difficult to distinguish between dissepiments and tabulae.

Several cystimorphs have been illustrated from Lower Devonian strata, but their generic relations are uncertain. These are three from the Eastern Alps (Charlesworth, 1914, pl. xxxii), three from the Eastern Urals (Tschernychew, 1893, pl. xiv, figs. 9, 18, 19), one from the Western Urals (Sochkina, 1937, pl. xv, figs. 5, 6), a phaceloid form from Maryland, U.S.A. (Swartz, 1912, pl. xxi, figs. 7-9), and two haploid species from Koněprus, Bohemia (Počta, 1902, pl. 117, fig. 3, pl. 105, figs. 1, 2).

Wedekind (1924) has illustrated several Couvinian cystimorphs under his new genera *Zonophyllum, Pseudozonophyllum* and *Lekanophyllum.* The detailed structure of the remnants of septa in these forms has not been described, but many of the dissepiments have truncated oval transverse sections; this character I have never seen in any Silurian cystimorph, but it is present in many Devonian cystimorphs. Stumm (1937, p. 440) placed three American Couvinian cystimorphs in *Mesophyllum* Schlüter, but they do not appear to me to be congeneric with the genotype, *Mesophyllum defectum* Schlüter as figured by Wedekind (1925, pl. 13, fig. 76). Two of them show a marked distinction between dissepimentarium and tabularium; none show any trace of the fossula which characterizes the *Mesophyllum-Mochlophyllum* group. None of the Devonian cystimorphs which I have examined show holacanths; but Wedekind (1937, pl. vii, fig. 1) gives a diagram which possibly indicates that true *Cystiphyllum* with holacanths existed at the base of the Couvinian.

In the German Givetian cystimorphs it is apparent that the septal remnants are of septa whose trabeculae were monacanths arranged in single radial series, close enough together in each series to form a septum pinnately fibrous about its median plane. Amongst them is an easily distinguishable group in which the septal remnants are visible only in successive zones of skeletal dilatation; each zone of dilated tissue is deposited on one old skeletal floor, and the dilatation is greatest in the middle of the floor, and decreases towards the periphery; as the calical floor is conical in all these forms, the zone of dilatation is conical also. This group includes *Cystiphyllum pseudoseptatum* Schulz (1883, pl. xxiii, figs. 2-4), and possibly also part of *Cystiphyllum vesiculosum* Goldfuss; Wedekind (1925) and Wedekind and Vollbrecht (1931) have figured it under the generic names *Lythophyllum, Nardophyllum, Paralythophyllum* and *Plagiophyllum.* The cystimorphs *Mesophyllum defectum* Schlüter (see Wedekind's figure, 1925, pl. 13, fig. 76), *Cosmophyllum* Vollbrecht (1922) and *Atelophyllum* Wedekind (1925, p. 37)

seem to me to be a different group; they are without the successive cones of septal dilatation, and the remnants of septa have greater radial extension, and are in the form of "bars" at the periphery. *Diplochone* Frech (1886) from the boundary between the Middle and Upper Devonian has no septal remnants but has a very narrow dissepimentarium of elongate dissepiments, and a wide tabularium of large concave plates.

In the Upper Devonian, cystimorphs occur in Western Australia (Hill, 1936*b*, p. 27), and in Canada (Fenton and Fenton, 1924, p. 41).

"CYSTIPHYLLUM" sp.

(Plate XV, figs. 4, 5.)

One weathered fragment of a trochoid corallum was obtained from Loyola by Miss E. A. Ripper (Melbourne University, Geology Department No. 620). It increases in diameter from 15 mm. to 20 mm. in a distance of 12 mm. The calice and apex were not preserved and the epitheca was weathered off. Horizontal skeletal elements are dominant; they are distally arched and are roughly divisible into a peripheral zone of smaller plates steeply inclined from the periphery, about one-third as wide as the radius of the corallum, and an axial zone of larger plates, whose inclination becomes less steep towards the axis, where they are arched about a horizontal plane. They are without any regularity of position. One or two are truncated ovals in transverse section. They are dilated in zones, each zone presumably at the position of a past calice, and the dilatation appears to lessen from the periphery to the axis. The dilated tissue is fibrous, the fibres lying at right angles to the curvature of the plate. Individual trabeculae can be distinguished in it only near the periphery, where they are seen in vertical section to be about 0.5 mm. in diameter, and to consist of fibres directed upwards and outwards from their axes; that is, they are monacanths (Hill, 1936*a*, p. 194). In transverse section the trabeculae may sometimes be continuous from one dissepiment to the next, so that short radial fragments of septa are present, about 0.5 mm. thick.

REMARKS.—The fragment differs from the Silurian Cystiphyllids and resembles Devonian cystimorphs in having monacanthine and not holacanthine trabeculae. It differs from the Lower Givetian Cystiphyllids described by Wedekind (1925, p. 32), as *Lythophyllum* in having the dilatation of its horizontal skeletal elements increasing from the axis outwards. Truncated oval sections of dissepiments are common in Devonian cystimorphs, and one or two occur in this Loyola specimen. The specimen cannot be regarded as of any great significance for the determination of the age of the limestone, but it indicates the Devonian rather than the Silurian.

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Plate XIII.

Rugose Corals from Lilydale and Canada.

All figures, except figures 1, 8, and 9, approximately × 2 diameters.

Fig. 1.—*Prismatophyllum chalkii* (Chapman). Holotype, from Lilydale. Chapman Collection. Natural size.
Fig. 2.—The same. Topotype 626, Melbourne University Geology Department Collection. Transverse section.
Figs. 3-4.—The same. Topotype 628-9, Melbourne University Geology Department Collection. Oblique section.
Fig. 5.—The same. Topotype 627, Melbourne University Geology Department Collection. Vertical section.
Fig. 6.—*Prismatophyllum stevensi* (Chapman), holotype. Vertical section 624, Geological Dept., Melbourne University. Lilydale.
Fig. 7.—The same. Transverse section, 625, same collection.
Fig. 8.—*Mictophyllum nobile* Smith, holotype, Geol. Surv. Canada Colln. Frasnian, Mackenzie R. Canada. Transverse section. × 1½ diameters.
Fig. 9.—The same. Vertical section. × 1½ diameters.

Plate XIV.

Rugose Corals from Lilydale.

All figures approximately × 2 diameters.

Fig. 1.—*Lyrielasma subcaespitosum* (Chapman), holotype, 1731, National Museum, Melbourne. Transverse section.
Fig. 2.—The same. Transverse section.
Figs. 3*a*, *b*.—The same. Vertical sections.
Figs. 4*a*, *b*.—The same, topotype F 1329*a*, Australian Museum, Sydney. Vertical and transverse sections.
Fig. 5.—The same, topotype F 1329*b*, Australian Museum, Sydney. Vertical section.
Fig. 6.—The same. Transverse section.
Fig. 7.—*Mictophyllum creswelli* (Chapman), topotype F 1146, Australian Museum. Transverse section.
Fig. 8.—The same. Vertical section.
Fig. 9.—The same, topotype 630, Melbourne University Geology Department Collection. Vertical section.
Fig. 10.—The same, topotype F 1242 Australian Museum, Sydney. Vertical section.
Fig. 11.—The same. Transverse section.

Plate XV.

Rugose Corals from Loyola.

The figured sections and the specimens from which they were cut are in the Geology Department, University of Melbourne.

All figures approximately × 2 diameters.

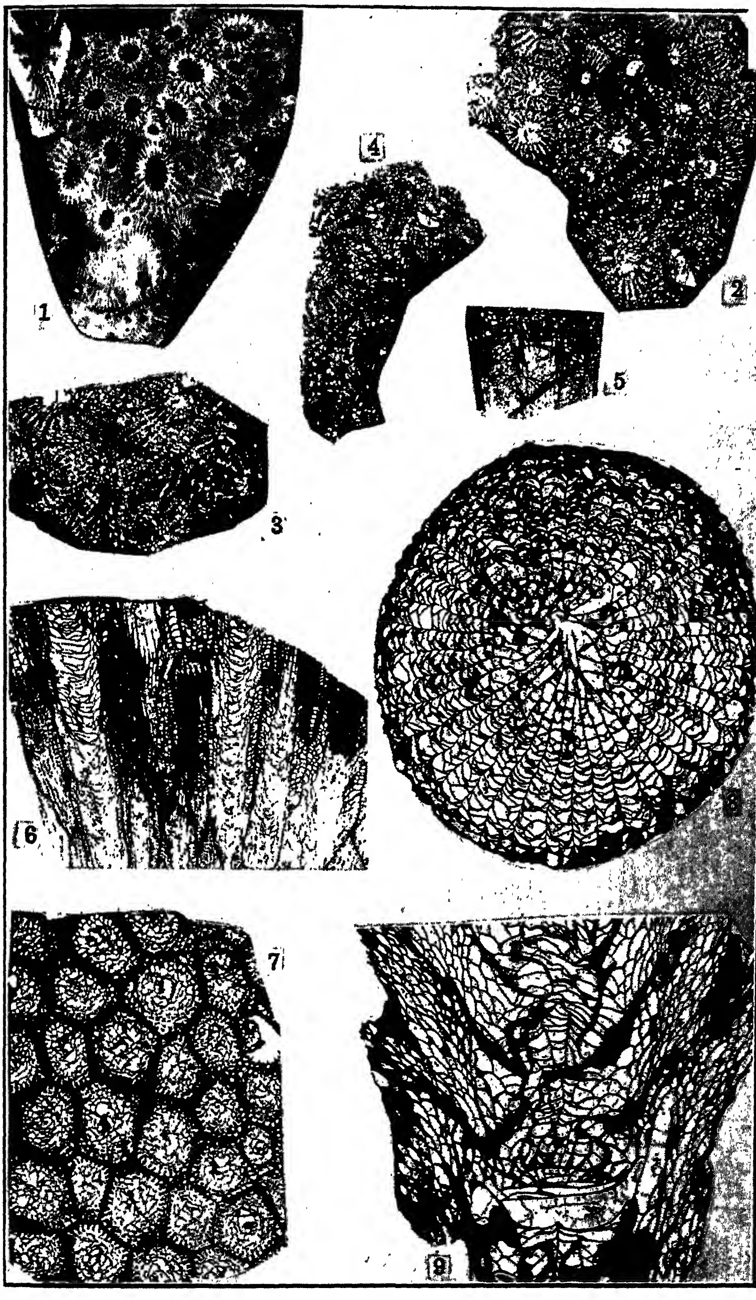
Fig. 1*a*.—*Acanthophyllum mansfieldense* (Dun), topotype. Transverse section 608.
Fig. 1*b*.—The same. Lighter print of central part of fig. 1, to show the waving and carinae of the septa.
Fig. 2.—The same. Vertical section 609.
Fig. 3.—The same, topotype. Transverse section 610.
Fig. 4.—"*Cystiphyllum*" sp. Transverse section 620*a*.
Fig. 5.—The same. Vertical section 620*b*.
Fig. 6.—*Lyrielasma subcaespitosum* (Chapman), transverse section 621.
Fig. 7.—The same, 622.
Fig. 8.—*Loyolophyllum cresswelli* Chapman, topotype. Transverse section 616.
Fig. 9.—The same. Oblique section 617.
Fig. 10.—The same. Vertical section 618.
Fig. 11.—The same. Transverse section 619.
Fig. 12.—Gen et sp. indet. Oblique section 623.

Plate XVI.

Rugose Corals from Loyola.

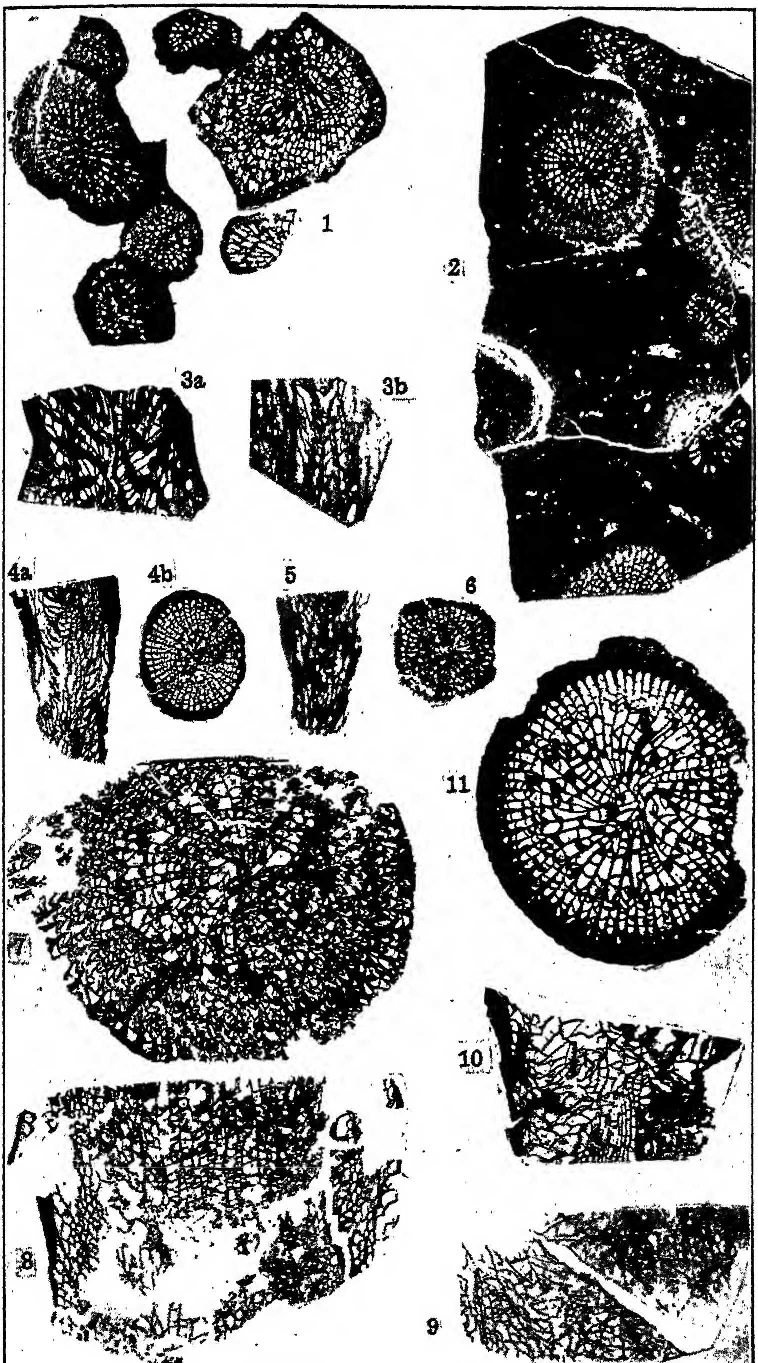
All figures approximately × 2 diameters.

Fig. 1.—*Phillipsastraea speciosa* Chapman, holotype, 2487 Geological Survey of Victoria. Vertical section 1388, National Museum, Melbourne.
Fig. 2.—The same. Transverse section 1387, National Museum, Melbourne.
Fig. 3.—The same; topotype, University of Melbourne; Geological Dept. Transverse and part of a vertical section (611) through corallum with septa withdrawn from the tabularium.
Fig. 4.—The same. Vertical section 612.
Fig. 5.—*Phillipsastraea* sp. indet., 2491, Geological Survey of Victoria. Transverse section 1374, National Museum, Melbourne.
Fig. 6.—The same. Oblique section 1375, National Museum, Melbourne.
Fig. 7.—*Thamnophyllum reclinatum* sp. nov., holotype, R 25186, British Museum (Natural History), London. Transverse section.
Fig. 8.—The same. Vertical section.
Fig. 9.—*Trapezophyllum elegantulum* (Dun), topotype of genotype, University of Melbourne, Dept. of Geology. Transverse section 613.
Fig. 10.—The same. Vertical section 614.
Fig. 11.—The same. Vertical section 615.

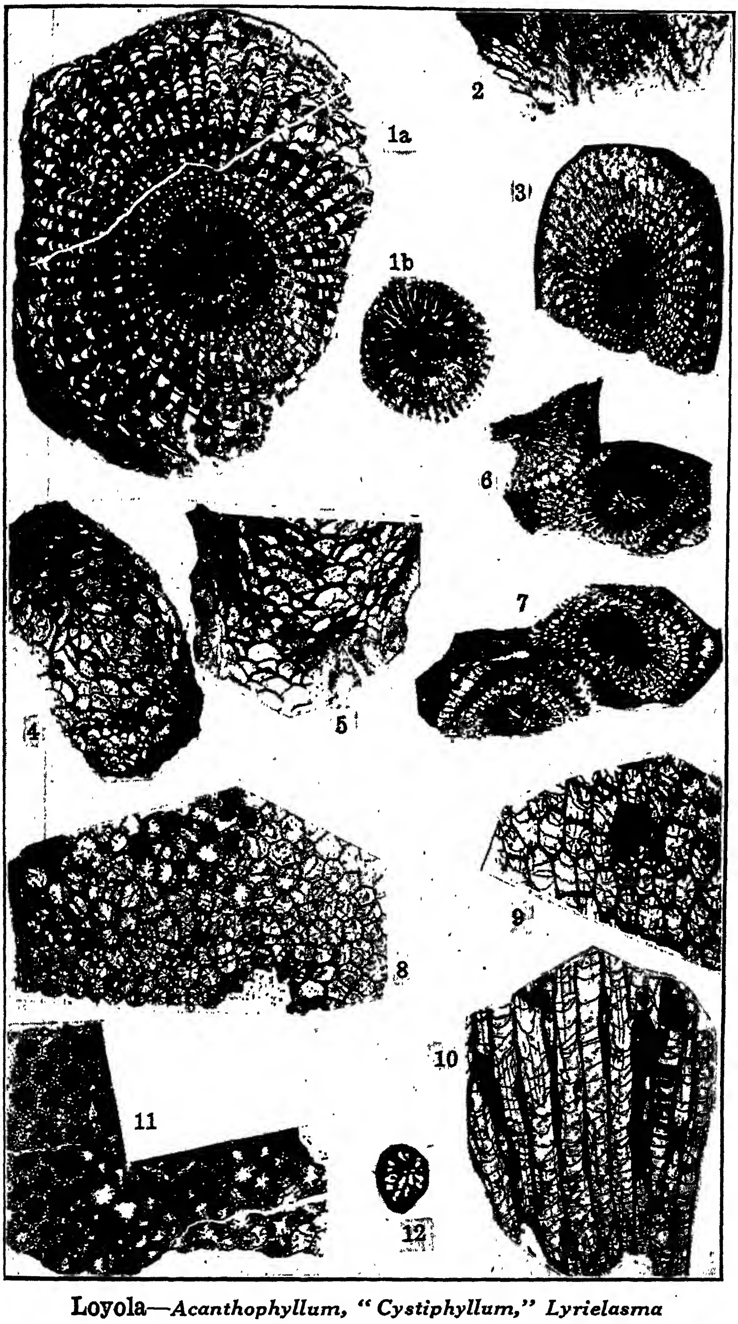


Lilydale—***Prismatophyllum.***
Canada—***Mictophyllum.***

[*Page 257.*]

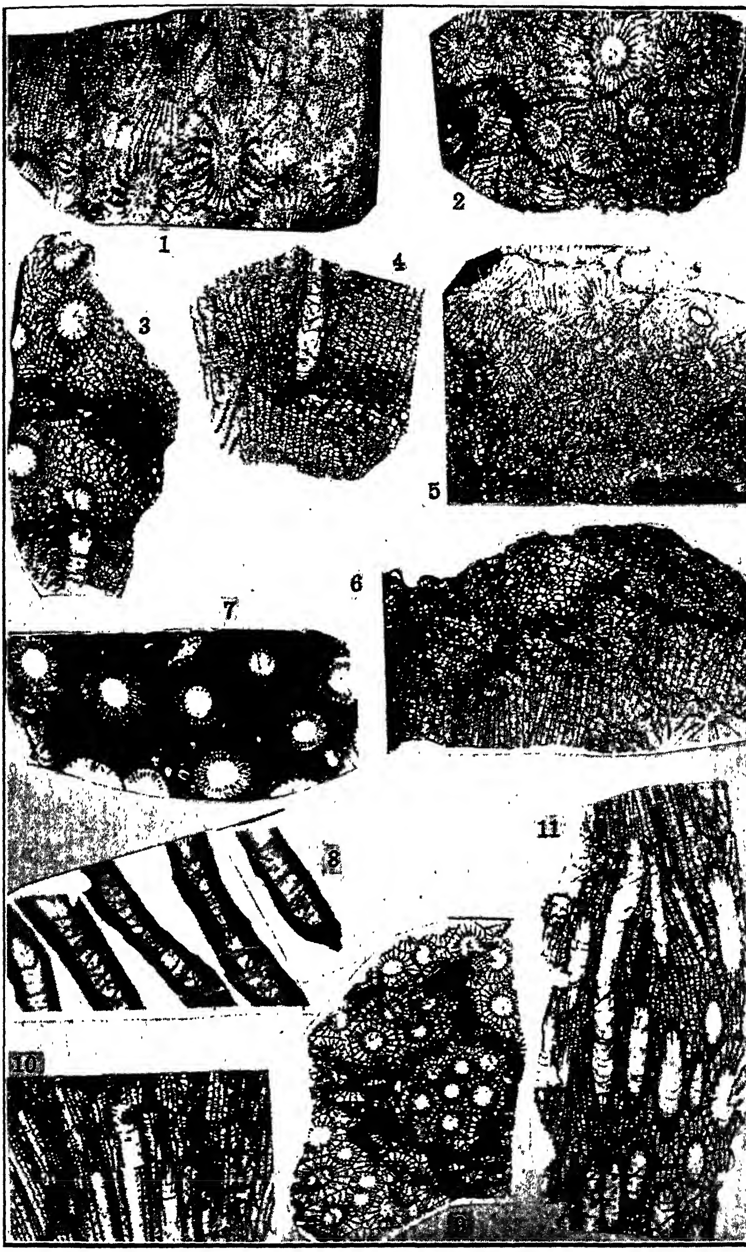


Lilydale—*Lyrielasma* and *Mictophyllum.*



Loyola—*Acanthophyllum, "Cystiphyllum," Lyrielasma* and *Loyolophyllum.*

[*Page 261.*]



Loyola—*Phillipsastraea, Thamnophyllum, Trapezophyllum.*

[PROC. ROY. SOC. VICTORIA, **51** (N.S.), Pt. II., 1939.]

ART. XII.—*Studies on the Australian Clavariaceae. Part II.*

By STELLA G. M. FAWCETT.

[Read 8th December, 1938; issued separately, 24th July, 1939.]

Genus **Clavaria** (*continued*).

In a previous contribution (Proc. Roy. Soc. Vic., n.s. LI. (1), pp. 1-30), the groups 3, 4, 7, 8, and 9 of this genus, as classified by Coker, were dealt with. In this part it is proposed to describe the groups 1, 2, 5, and 10.

GROUP 1 (incomplete).

CLAVARIA AURANTIA Cke et Mass. Grev. XVI., 33, 1887.

(Plate XXII., fig. 3, text fig. 1A.)

Plants simple, solitary, 6–9 cm. high and 2–4 mm. broad. Stem distinct but not sharply delimited, whitish, rather woolly, 1.5–2 cm. long. Club cylindrical, slightly thickened upwards, smooth, except for a few longitudinal rugae, tips bluntly rounded. Colour Orange Chrome. Flesh solid, somewhat fibrous, colour near to Apricot Yellow, pliable, not at all brittle. Taste and smell, none, or very mild.

Spores copious, white, smooth, sub-globose to elliptical: 3.9–6.1 × 6.2–7.7 μ with one large guttule. Locality: Turton's Pass, Tanybryn; on ground on hillsides.

This species may be distinguished by its deep dark orange colour, solitary habit and elongated, cylindrical clubs. It is recorded from only one locality in Victoria.

Coker has examined a plant of this species (Bresadola Herb. No. 50) and gives a spore measurement which agrees very closely with that of the plant as we know it. He points out the similarity between this plant and *C. aurantio-cinnabarina* Schw. Cooke's illustration of *C. aurantia* suggests our plant in shape and habit, but is rather lighter in colour.

CLAVARIA CAEPICOLOROSA n. sp.

(Plate XIX., figs. 2, 3, 4, text fig. 1B.)

Plantae simplices, gregariae, raro caespitosae, 4–10 *cm. alt,* (*nonnunquam ad* 15 *cm.*), 5–6 *mm. latae* (*nonnunquam* 1.5 *cm. latae*). *Stirps cylindrica, octava pars ad quarta pars plantae altitudine cum radicibus non profundis levis aliquantum fulgens multo angustior quam clava, nonnunquam maxime distincta tomentosa ad basem, "English Red" aut minus rubra.*

Clava valde cylindrica, aliquantum flexuosa, plerumque levis, sed nonnunquam rugulosa et dilata. Apices obtusae et rotundae nonnunquam dilatae. Colour " Onion Skin Pink" juvenis, postaea "Japan Rose," "Congo Pink," "Terra Cotta," "Orange Vinaceous." Caro solida magis colorosum et magis translucens juxta hymenium, in media parte clavae mollis et postea exesa. Fragilis facile fracta cum flecta, in aetate cava et saepe exese ab vermiculis. Sporae albae, subglobosae, 7–9 μ latae, leves cum minuto apiculo et una magna gutta.

Hab. ad terram.

Loc. Fairyland, Apollo Bay.

Plant simple, gregarious, rarely caespitose, height 4–10 cm. (sometimes to 15 cm.), 5–6 mm. broad (sometimes to 1.5 cm. broad). Stem cylindrical, $\frac{1}{8}$–$\frac{1}{4}$ the height of the plant, not deeply rooting, smooth, slightly polished, much narrower than the club, sometimes sharply delimited, hairy at the base, English Red or lighter in colour.

Club stoutly cylindrical, somewhat flexuous, generally smooth but sometimes rugulose and flattened. Tips blunt and round. sometimes flattened. Colour Onion Skin Pink when young, later Japan Rose, Congo Pink, Terra Cotta or Orange Vinaceous. Flesh solid, darker and more translucent just below the hymenium; in the centre of the club, loose, soft and fibrous, tending to tear apart into hollows. Brittle, splintering or snapping with a clean break when bent, hollow in age and frequently attacked by grubs. Spores white, sub-globose, 7–9 μ in diameter, smooth, with a minute apiculus and a single large guttule. Habitat—on ground in gullies, on cliffs and among grass in cleared land. Locality: Fairyland, Apollo Bay.

This is a well-marked species, obviously related to *C. aurantia*. In the field it can be recognized by its colour, stout, more or less cylindrical, clubs and constricted stem.

CLAVARIA ACUTA Fr. ex Sow. Sow, Engl. Fungi, pl. 333, 1803.

?*C. falcata* Pers. Comm. p. 81 (213), 1797.

(Text fig. 1 (D).)

Plants simple, single or in small caespitose clumps, between 2 and 5 cm. high. Stem equal to about one-third the plant or less, translucent, shining, glistening with minute, scurfy projections. Club thickened upwards, often expanded at the tip and bluntly bilobed, sometimes cylindrical, but more often flattened Flesh solid, translucent, soft and very fragile, breaking cleanly when even slightly bent. Taste and odour none. Colour, pure milky white.

Spores white, smooth, sub-spherical but with one side definitely flattened and with a distinct apical mucro, 7–8.5 × 8–10 μ. Growing on bare ground in gullies or among moss in heathland.

Localities: Otway Forest, Cockatoo, Mt. Evelyn, Phillip Island. Not previously recorded for Australia.

This species can be readily recognized by the pure white colour, translucent, shining stem, extreme fragility and by the sub-spherical spores which show one flattened side. It is obviously closely related to *C. rosea* (sensu Cotton and Wakefield) and to *C. luteostirpata.*

Clavaria luteostirpata n. sp.

(Plate XIX., fig. 5, text fig. 1 (o).)

Plantae simplices, singulae, aut caespitosae in parvis fascibus, gregariae, 3–7 cm. altae, stirps aequalis ad tertiam partem planti, distincta sed in hymenium mergens, teretis, levis et fulgens. " Empire Yellow " cum radicibus non profundis. Subiculum non obvium. Clava 2–5 cm. longa, 2–5 mm. lata si cylindrica, 3–4 mm. si dilata, recta aut magis sinuosa, saepius cum apice latiore, nonnumquam compressa et raro cum uno aut duobus cornibus in apice. Apices obtusae, leniter spiculatae. Colour " Pinard Yellow," magis translucens cum juvenis. Caro clavae similis coloris quam exterior pars, mollis, fragilis, stirps cum cortice cartilaginosa sed mollior ad interiorem partem.

Sapor et odor nullus aut blandissimus.

Sporae albae, leves, sub-globosae, cum apiculo prominenti, 6.2–9 × 7.3–10 μ *av.* 7.5–8.8 μ, *cum magna gutta.*

Hab. ad terram. Loc. Cockatoo.

Plants simple, solitary or caespitose in small groups, gregarious, height 3–7 cm., the stem equal to one-third of the plant, distinct, but grading into the hymenium, terete, smooth and shining, Empire Yellow, not deeply rooting, subiculum not obvious, club 2–5 cm. long, 2.5 mm. wide if cylindrical, 3–4 mm. if flattened, straight or rather flexuous, usually broader at the apex, sometimes compressed and rarely with one or two antler-like branches at the apex. Tips bluntly pointed, gently tapered. Colour Pinard Yellow, rather translucent when young. Flesh of club, concolorous, soft, brittle, stem with a cartilaginous rind but softer in the centre. Taste and odour none or very mild.

Spores white, smooth, sub-globose, with a prominent apiculus, 6.2–9 × 7.3–10.4 μ, average 7.5–8.8 μ, with a large guttule. Habitat—on ground in gullies. Localities: Cockatoo, Otway Forest.

This is a very well-marked species and can be readily distinguished by the shining yellow stem and paler, rather translucent club. It is near to *C. appalachiensis* Coker but differs in its smooth hymenium and larger spores. It is obviously related to *C. rosea* (sensu Cotton and Wakefield) as the spores are very similar and this plant has also a shining stem and paler club. The two species are very often found growing together.

Group 2.

Clavaria fusiformis Fr. ex Sow. Sow. Engl. Fung., pl. 234, 1799.

C. fasciculata Villars. Hist. Plant. Dauph., 3: 1052, 1789.
C. platyclada Pk. Bull. Torrey Bot. Club, 23: 419, 1896.
C. compressa Schw. Trans. Am. Phil. Soc. II., 4: 182, 1832.
(Not *C. compressa* Berk. or *C. compressa* Schroet.)
C. ceranoides Pers. Syn. Met. Fung., p. 594, 1801.

(Plate XVII., figs. 4 and 5, text fig. 1 (L).)

Plants simple, usually growing in dense clusters, 4–6 cm. high, and 2–4 mm. wide, solid, sometimes cylindrical but more often flattened, at times thickened upwards, and spatulate at the tips, again thickened to about the middle and tapering to a blunt point at the apex. Base not distinct. Flesh firm, paler than the surface, opaque, solid, (not often with a hollow in the centre as in American and European plants). Moderately brittle, not snapping with a clean break when bent. Colour Light Cadmium or Empire Yellow, Capucine Buff in age. Taste varies from mild to bitter, smell none. Spores 5–7 μ diameter, globose, smooth with a very distinct abrupt apiculus, with or without a large central gutta. Spore deposit yellow or white (this character has been observed in American plants, but the spores show no differences microscopically). Habitat—on ground in open or sheltered places, sometimes on buried sticks. Widespread in Victoria. Not previously recorded for this State. There is a multiplicity of species of simple yellow *Clavarias* in Victoria, some of which are difficult to determine accurately, but among them *C. fusiformis* can be readily identified by the following characters:—

1. Fascicled habit.
2. Bright, opaque, egg-yellow clubs.
3. Blunt tips and generally flattened clubs.

Clavaria vermicularis Fr. ex Micheli. Fr. Syst. Myc. 1, 484, 1821.

Micheli Nova Plant Gen., p. 209, pl. 87, fig. 12, 1729.
(as *C. vermiculata*).
C. cylindrica Bull. Herb. Fr., p. 212, pl. 463, fig. 1, 1789.
C. fragilis Holmsk. Beata Ruris, 1: 7, pls. 2 and 3, 1790.
C. gracilis Sow. Engl. Fung., pl. 232, 1797.
C. eburnea Pers. Syn. Met. Fung., p. 603, 1801.
?*C. canaliculata* Fr. Obs. Myc. 2: 294, 1818.
(not *C. canaliculata* Ehrenb.).
C. alba Pers. Myc. Europ., 1, 175, 1822.
(not *C. alba* Pers. ibid., p. 161).
C. pistilliforma Pers. Myc. Europ., 1: 183, 1822.
?*C. corynoides* Pk. Rept. N.Y. St. Mus., 31: 39, 1879.
C. nivea Quel. Assoc. Francaise, p. 3, pl. 3, fig. 11, 1901.
(22nd supplement to Champ. Jura, etc.).

(Text fig. 1 (E).)

Plants most often gregarious, sometimes single. Simple or very sparingly branched, up to 4 cm. high and 2–3 mm. broad. Stem not distinct, clubs pure white, thickened upwards, bluntly pointed. Flesh, white, rather translucent, very brittle. Taste and smell, none. On drying the plants become Isabella Colour and on being placed in water regain their former shape instantly.

Spores, globose, smooth, hyaline, minutely apiculate, 3–5 × 3–4 μ. Basidia with four sterigmata. Habitat—on ground in gullies. Locality: Dandenong Ranges.

Cooke records this plant for Victoria but gives the spore measurement as 8 × 6 μ. If these spore measurements are correct it is possible that he had either *C. cristata* (*rugosa* form) or *C. acuta.* Coker calls this plant *C. vermiculata* Micheli but according to the Rules of Botanical Nomenclature, the Friesian name *C. vermicularis* is valid.

This species can be distinguished from *C. acuta* by its more slender habit, indistinct stem, smaller spores and by the fact that it tends to grow in groups. Dried plants of *C. acuta* do not instantly regain their shape on moistening.

CLAVARIA CORALLINO-ROSACEA Clel. Aust. Fungi: Notes and Descriptions, No. 8. Trans. S.A. Roy. Soc., Vol. LV., 1931, pp. 152-160, 1931.

(Plate XXII., figs. 5 and 6, text fig. 1 (B).)

Plants simple, occasionally antlered, growing in large colonies, but the bases usually separate. Height up to 12 cm., commonly 6–9 cm., breadth up to 5 mm., commonly 2–4 mm.

Stem not distinct, rather smoother than the club, slightly polished. Clubs broadest in the middle, attenuated above and below, tapering to a blunt point at the apex, generally flattened and ribbon-like, flexuous, quite frequently cylindrical and straight. When young, smooth, later developing longitudinal wrinkles. Flesh solid, concolorous beneath the hymenium, paler in the centre of the club. Taste slight, pleasant and sweet, similar to that of *C. pulchra;* smell similar, persisting in dried plants. Colour, Coral Pink, Light Coral Red, Coral Red, fading in age, and paler and more yellowish in underground parts.

Spores, white in thin layer, same colour as the club when scraped together, 7–10 × 3–4.4 μ. Once or twice guttulate, smooth, obliquely pip-shaped, pointed at both ends when mature, rounded at the distal end in youth. Basidia with 2 or 4 sterigmata. Hyphae 4–5 μ wide, containing many oil droplets. Habitat—on ground, very widespread in Victoria.

Cleland first recorded this plant as *C. rosea* but later described it as a new species. The plants he described are generally smaller and have shorter spores than the Victorian plants. In addition, he describes the spores as "somewhat pear-shaped, 6 × 3.4–4 μ". Cleland examined a collection of the Victorian plant and says that it is undoubtedly *C. corallino-rosacea.*

He records the plant for New South Wales and South Australia but, although widespread in this State, it has not been previously recorded here. A plant, No. 249, in the Rodway Herbarium is probably this species. It shows no spores.

CLAVARIA PULCHRA Pk. Rept. N.Y. St. Mus. 28: 53, pl. 1, fig. 10, 1876.

C. angustata Pers. (Sense of Schw.) Comm., p. 72, 1797.
C. persimilis Cotton, Trans. Brit. Myc. Soc. 3: 182, 1909.

(Plate XIX., fig. 1, text fig. 1 (G).)

Plants gregarious, caespitose in small clusters, or occasionally single. Up to 12 cm. high, 1 cm. broad and 4 mm. thick. Sometimes cylindrical with a bluntly pointed tip, more often flattened and channelled, usually flexuous; rudimentary branches often present. Clubs thickened upwards, stem smooth, glabrous, narrower than the club, but not sharply delimited. Hymenium smooth or with a few longitudinal wrinkles. Flesh soft, whitish in the centre, rather fibrous, pliable, not brittle, but breaking when bent upon itself. Taste and odour, sweet, like that of *C. corallino-rosacea*. Colour, Cadmium Yellow, Flame Scarlet to Orange Chrome, Capucine Yellow to Deep Chrome, Light Cadmium to Pinard Yellow. Base whitish for a variable distance upwards. Spores, oblong-elliptical, with a prominent oblique mucro, white, 4.2–5.3 × 6.7–7.8 μ. Habitat—on ground in forest country. Widespread in Victoria. Not previously recorded for Australia.

This plant shows most of the characters of *C. pulchra* as understood by Coker but the spores, although similar in shape, are narrower than and show a greater range in length than the American plants.

C. pulchra can be distinguished from *C. fusiformis* by (1) oblong spores, (2) deeper orange colour, (3) rather more irregular clubs, (4) lack of strongly fascicled habit.

GROUP 5.

CLAVARIA MIYABEANA S. Ito. Trans. Sapp. Nat. Hist. Soc., Vol. XI., Pt. 2, p. 72, 1930.

(Plate XXIII., text fig. 1 (J).)

Plants commonly densely caespitose, sometimes in loose clusters, rarely single, 3–14 cm. high, 0.5–7 cm. broad. The smaller plants are generally simple and club-like, at first almost cylindrical, later flattened, thickened upwards, and with a distinct broad groove on either side, edges rounded, apex broadly obtuse or showing one or two rudimentary antler-like branches. Larger plants assume very varied and fantastic shapes, very much flattened and expanded laterally with a sinuous, often inrolled

margin and with many fine longitudinal striations; or knobbed and irregular at the apex, tapering to a slender base; or forming a dense convoluted, compact mass. Base not sharply delimited, often deeply rooting, sometimes attached to buried sticks, concolorous or whitish. Flesh, solid, rather loose in irregular specimens, paler than the surface. Taste and smell, slight and pleasant. Colour: Grenadine and Grenadine Red.

Basidia with two or four sterigmata, spores white in mass, globose, smooth, with a well-marked apiculus and a large central gutta, 6.3–8.2 × 6.5–8.5 μ. Habitat—on sandy soil under bracken and on peaty soils in swampy areas. Localities: Hordern Vale, Hedley.

Not previously recorded for Australia. This is easily the most spectacular species of Clavaria that occurs in Victoria and can be easily recognized by its brilliant, orange-red colour, by its large size and generally contorted clubs. It agrees very closely with the description of the type. It is known to a number of people at Hedley as the "Flame Fungus" and it appears worth while to retain this as the vernacular name for the species as it is so descriptive. This species, particularly in those specimens which are very much flattened and expanded, apparently shows affinities with *Craterellus* as do *Clavaria pistillaris* and *Clavaria ligula.*

Clavaria pallidorosea n. sp.

(Plate XX., fig. 2, text fig. 1 (Q).)

Plantae singulae aut gregariae in parvis fasciculis, 6–11 *cm. alt,* .5–1 *cm. lat. Basis rotunda, saepe cava, brevis, cum radicibus non ex profundo surgentibus, junctio cum hymenio inaequalissima. Clava saepissime latescens et torquens, cum multis rugis in longitidinem, nonnullae latis. Apices obtusae, rotundae, aut latescentes et se dividentes in duos ramos cornutos. Colour " Bittersweet Pink " cum nota crocea in apice. In aetate aut sicca magis lutea. Caro solida " Grenadine Pink ", opaca, fragilis facile fracta flectendo, nonnumquam cava ad basem. Sapor et odor dulcis, similis ad C. corallino-rosacea. Interior pars habet tenues hyphas inter se innectentes. Basidia clavata, cum duobus aut quattior sterigmatis. Sporae leves, in massa albae, globosae cum apiculo recto et prominenti* 4.8–6.9 × 5.1–6.9 μ (*av.* 5.4 × 5.9 μ), *una magna gutta. Hab. ad terram carbonaceam. Loc. Labertouche.*

Plants single or gregarious in small clusters, 6–11 cm. high, 0.5–1 cm. broad. Base rounded, often hollow, short, not deeply rooting. Junction with hymenium very irregular. Club typically flattened and twisted, finely rugose, with a few broad longitudinal wrinkles. Tips obtuse and rounded or flattened and divided into two antlered branches. Colour: Bittersweet Pink, with a hint of orange at the tip, creamy yellow in age or on drying. Taste and smell, sweet and pleasant, rather like *C. corallino-rosacea*

Flesh solid, Grenadine Pink, opaque, brittle, snapping when bent, sometimes becoming hollow towards the base. Internal structure of fine, slightly interwoven hyphae. Basidia clavate, with two or four sterigmata. Spores smooth, white in mass, globose, with a prominent, straight apiculus, 4.8–6.9 × 5.1–6.9 μ (av. 5.4 × 5.9 μ) with one large central gutta. Habitat—on burnt ground. Locality: Labertouche.

The colour and habit of this plant suggests *C. pistillaris,* but the spores of the latter are much larger (9–18 μ long). It can be readily distinguished in the field by its stout habit, orange-pink colour, and globose spores. It is obviously related to *C. Miyabeana,* but differs in colour, is more regular in habit, and has smaller spores.

Group 10 (incomplete).

Clavaria sinapicolor Clel. Aust. Fungi Notes and Descriptions No. 8. Trans. Roy. Soc. S.A., Vol. LV., 1931, pp. 152-160.

(Plate XXI., figs. 1–7, 9, text fig. 1 (c).)

Plants massive and branched, up to 12 cm. high and 9 cm. broad, growing singly, or small and slender, occasionally growing singly but generally in extensive clumps, either free or partially fused at the base. It is obvious that large single plants have arisen through the fusion of several or many individuals, as in almost any large colony of this plant a series of plants showing progressive stages of complexity due to the fusion of separate individuals can be found.

Base of simple plants, cylindrical, somewhat pointed below, branching dichotomously near the ground into two branches which are not markedly different from the stem in size. These primary branches usually elongate a great deal before branching in a similar fashion, and after this may branch once or twice to form the ultimate tips which are long, upright or flexuous, and cylindrical, tapering to blunt tips. Axils rounded, but trend of the branches upright, a furrow descending from either side of each axil, branches cylindrical but somewhat flattened at each axil.

The branching of the complex plants is similar to that of the simple ones. The trunk may be slender, vertical rugae indicating that the plant is the result of the fusion of several; or if stout, composed of many fine compacted stems. Colour, Naples Yellow, Mustard Yellow, Straw Yellow, Light Orange Yellow. Flesh white, or pale creamy yellow, solid. Taste mild, smell sweet, rather like that of broome or gorse, strong in age. Spores ochraceous, elliptical, moderately rough, with an oblique apiculus 3–4.5 × 6–8–10 μ. There is some indication that on the whole large plants produce longer spores than small plants.

This is a very abundant species in Victoria and has been collected between March and November. It can be distinguished by the generally tufted habit, yellow colour and upright, cylindrical branches with somewhat flattened axils

CLAVARIA FENNICA Karst. Nat. Sällsk. Faun. et Flora Fenn. 9, 372, 1868 (not *C. fennica* Karst. Bidr. Finl. Nat. Folk. 48: 47, 1889. = *C. decolorans* Karst. Symbolae ad Myc. Fenn. 32: 10, 1893.).

?*C. rufo-violacea* Barla Champ. Nice, p. 87, pl. 41, figs. 3-13, 1859.
C. fumigata Pk. Rept. N.Y. St. Mus. 31, 38, 1879.
Ramaria versatilis Quel. in Assoc. Fr. Av. Sci. Compte Rendu 22, Pt. 2, 489 (1893), 1894.
C. versatilis Quel. (Boud. and Galzin) Bull. Soc. Myc. Fr. 26: 214, 1910.
Clavariella versatilis (Quel.) Maire Bull. Soc. Myc. Fr. 30: 218, pl. 9, figs, 1, 1*b*, 1*s*, 1914.

(Plate XVIII., fig. 2, text fig. 1 (M).)

Plant branched and bulky up to 5 × 5 × 10 cm. Base typically stout and distinct, more or less cylindrical, often bulbous, attached to the soil by a few inconspicuous fibres. Branches arising as in *C. botrytis,* i.e., beginning as knob-like projections on the upper part of the trunk, and elongating until maturity. Branching irregular or sub-dichotomous, the ultimate tips being produced after three or four divisions. These tips are generally truncate and cylindrical, bearing a few small cusps, or rarely toothed and flattened, giving a palmate appearance, and are so densely crowded as to obscure the main branches. Large primary branches, if present, are rugose and up to 6 mm. wide, secondary branches 4 mm., tertiary branches and tips about 1.5 mm. wide.

Flesh, soft, white or creamy, opaque, composed of interwoven hyphae. Taste, indistinct and mild. Colour, whitish at base of stem, Deep Dull Lavender in upper parts. In age, the entire plant becomes Vinaceous Drab with the purple colour disappearing (except at the top of the stem) until finally the plant is a smoky greyish green with only a suggestion of purple at the tips, on the main branches, and top of the stem.

Spores, ochraceous in mass, microscopically slightly coloured, elliptical with an obliquely terminal mucro, evenly and finely warted, 4.5–5.8 × 10.3–11.1 μ. Basidia with four straight sterigmata. Habitat—on ground. Localities: Macedon, Eganstown, Mt. Wilson.

The spores of this plant are slightly longer and wider than those of the European specimens, which have spores 3.7–4.4 × 9.8–11 μ, but in other features the plants are similar. *C. fennica* as understood by Bresadola has a purple stem and greenish-yellow branches but it is otherwise similar to the Victorian plant. It is possible that the plants illustrated by Bresadola are over-mature specimens. *C. fennica* has not been previously recorded for Australia but a purple Clavaria, painted by the late Mrs. Ellis Rowan, is probably *C. fennica.* Cleland suggested that the painting might be of *C. vinaceo-cervina* but this species never shows the bright, rich purple or the rather regular branches of the plant illustrated.

C. fennica differs from *C. Nymaniana* in having a thick, glabrous base, deeper colour and roughened, elongated, ochraceous spores. Illustration: Painting by Mrs. Ellis Rowan, Victorian Field Naturalist, Vol. XLIX., No. 2, pl. ii.

CLAVARIA RUFESCENS Fr. ex Schaeff. Schaeff. Fung. Bavar. pl. 288, 1770.

C. holorubella Atk. Ann. Myc. 6: 57, 1908.
C. australiana Clel. Aust. Fung. Notes and Desc. No. 8 Trans. S.A. Roy. Soc., vol. LV. 152-160, 1931.

(Plate XX., fig. 1, pl. XXII., fig. 1, text fig. 1 (F), (K).)

Plants large, 10–12 (sometimes up to 20) cm. high, to 7 (sometimes 10–15) cm. wide. Stem rooting, distinct, stout, smooth, whitish, occasionally with picric yellow stains. A few large branches or many smaller ones arise directly from the trunk, these branching one to four times to form a mass of fine, cylindrical, rather abruptly truncate tips, which bear a few blunt cusps and form a rather loose mass. Axils slightly rounded, branches rugose or occasionally quite smooth. Colour, when young the body of the plant is Cinnamon Buff with the tips Vinaceous. At maturity the purplish colour becomes more pronounced and extensive, and the upper parts of the branches vary between Hydrangea Red and Dark Vinaceous. In age, the entire plant, with the exception of the base, takes on a brownish colour and the purplish colour of the tips is somewhat masked.

Taste, not distinct, mild. Flesh, white and soft, brittle in young plants, soft and somewhat pliable at maturity. Spores, elliptical, with an obliquely terminal mucro, roughened, longitudinally or obliquely striate, ochraceous in the mass. 3–4.5 × 12–15.5 μ. Localities: Cockatoo, Eganstown, Toolangi, Erica, Kallista, Kinglake.

This plant is moderately common in Victoria and can be easily recognized by its vinaceous tips and buffy-brown body. It has been very much confused with *C. botrytis* (for discussion of the differences between the species see under *C. botrytis*). Cleland's description of *C. australiana* only differs from that of *C. rufescens* in the character of the spores, which are described as "microscopically slightly coloured, elongated, oblique, mummy-shaped, not striate, 11–13–16 × 4.5–5.5 μ, rarely 8.5 × 4 μ". I have examined a specimen of *C. australiana* from Cleland's Herbarium and find that the spores are definitely obliquely striate, 10–13 × 4.5–5.5 μ. Thus the plant could be placed as *C. holorubella* Atk., but Coker, on good evidence, regards this as synonymous with *C. rufescens*.

CLAVARIA BOTRYTIS Fr. ex Pers. Pers. Comm., p. 41 (174), 1799. Fr. Hym. Eur. 667.

?*C. acroporphyrea* Schaeff. Fung. Bavar., pl. 176, 1763.
?*C. plebeja* Wulfen in Jacq. Misc. 2: 101, pl. 13, 1781.
C. purpurascens Paulet in Paulet et Lev. Icon. Champ., p. 113, pl. 194, fig. 6. 1855.
C. botrytoides Pk. Bull. N.Y. St. Mus. 94: 21 and 49, pl. 93, figs. 5-7, 1905.
C. conjuncta Pk. Bull. N.Y. St. Mus. 105: 16 and 42, pl. 102, 1906.

(Plate XVIII., figs. 1, 3, pl. XXII., fig. 4, text fig. 1 (P).)

Plants large, branched, up to 16 cm. wide and 12 cm. high. usually medium-sized, up to 8 cm. high, rarely small, 3–5 cm. high. Base solid, tapering, stout, not deeply rooting. Occasionally several plants arise together (pl. xviii., fig. 1), in which case the bases are distinct and relatively slender. Branching irregularly dichotomous, many branches arising directly from the top and sides of the trunk, branches knoblike in youth, at maturity elongated, more or less cylindrical in the upper parts, axils eventually somewhat rounded, with a furrow descending on either side. Tips of branches with a number of obtuse, short tips. At maturity the plant presents a compact cauliflower-like appearance but as the branches continue to elongate, in age the plant is straggling and loose.

Flesh, until maturity, white, solid, crisp, and brittle; in age, soft and lax, somewhat pliable, Pale Buff in colour. Colour of mature plant: base whitish, body of plant, Salmon Buff, tips Grenadine; in youth, the entire plant, with the exception of the white base, is Grenadine, and at maturity this colour is retained by many undeveloped twiglets at the base. In age, the entire plant fades to Salmon Buff or darker but vestiges of the bright pink colour are often apparent at the tips, even in decaying plants.

Spores, Light Buff Yellow, minutely rough to almost smooth, 3.8–4.2 × 7.5–10 μ elliptical, with an oblique, terminal apiculus.

This is an exceedingly common species in Victoria and may be readily identified by the bright pink tips, paler body, and the brightly coloured, undeveloped branches at the base. A pallid, whitish plant, resembling *C. botrytis* in every character except colour, has been collected at Warrandyte on several occasions. In all cases, it has been found growing closely associated with characteristic plants of *C. botrytis* and may be regarded as an abnormal form of it. Cooke records *C. botrytis* (calling it *C. botrytes* in error) for Victoria, Queensland, New South Wales, Western Australia and Tasmania. He places it in the group *Leucosporae* of the sub-genes *Ramaria* but this is incorrect as the spores are coloured. He, also, in common with Cotton and Wakefield and others, has apparently confused *C. botrytis* with *C. rufescens* as he gives the spore measurement as 12–15 × 6 μ. *C. botrytis* and *C. rufescens* can be easily distinguished

as the tips of the former are bright, clear pink becoming paler with age, and are typically thick, while those of *C. rufescens* are usually fine, and are somewhat dusky and Vinaceous Pink in youth, darkening with age. In addition, the spores of *C. rufescens* are obliquely striate and longer than those of *C. botrytis* which are almost evenly roughened. *C. rufescens* has a smooth, tapering base which never shows brightly coloured undeveloped branches.

C. botrytis is edible and quite pleasant to taste. It is apparently eaten by rabbits and possibly other animals; plants gnawed off to ground level and bearing marks of teeth are frequently found. Localities: Common in hilly country south of the Dividing Range. March to November.

CLAVARIA CAPITATA Lloyd. Myc. Notes, Vol. 7, p. 1107, 1922.
(Plate XVII., figs. 1, 2, 3, 6, pl. XX., fig. 3, text fig. 1 (N).)

Plants branched and bulky, several arising together from a mycelial mass, which binds the soil together. Trunk of plant not obvious as the plants branch close to the base, furrowed, apparently as a result of the fusion of separate stems, white, and frequently with numerous pale, undeveloped branches (or separate young plants) at the base. Primary branches up to 1.5 cm. in diameter, usually about 0.8 cm.; secondary branches arising in a group from the primary branches, upright and rather crowded, axils very acute, but the branches often bend sharply outwards before continuing their upward growth. The secondary branches may give rise to another series in a similar manner or may produce the ultimate tips. These at first consist of a number of sub-globose, non-viscid swellings at the end of each branch and soon after their formation, differ sharply in colour and texture from the body of the plant. Towards maturity, these tips expand laterally and often coalesce; thus the upper surface of the plant may become more or less continuous and is usually finely convoluted. When the tips are not at approximately the same level, smaller areas become continuous and the plant presents a terraced appearance. The increase in size of the tips tends to strain the lower parts of the plant and splitting frequently occurs at the axils. At maturity, the tips are extremely sticky to the touch but the rest of the plant is dry. Colour, body of plant Maize Yellow to Pale Orange Yellow. Tips paler than Honey Yellow but yellower than Chamois, semitranslucent. Flesh white, crisp and brittle, taste mild.

Spores 11–13 × 4.2–5 μ. Elliptical, with a prominent oblique apiculus, definitely rough, ochraceous in mass, microscopically hyaline. Basidia most frequently with two, sometimes with four, sterigmata, hymenium covering the branches as well as the tips, clamp connections not seen.

The hyphae composing the body of the plant are only slightly interwoven and rather broad. In the young state the hyphae composing the tips are closely compacted and as the plant matures they proliferate and become much finer, intertwining freely. It is at this stage that fusion between closely approximated tips occurs and this accounts for the fact that small, closed pockets, lined with fertile hymenium, may often be observed in prepared sections of the tip region. The growth at the tips is not so much in a vertical direction as lateral, and results in the curling back of free edges of the tips. Finally, these tips develop normal basidia but this occurs later than on the branches (this may account for Lloyd's statement that the branches are sterile). The stickiness of the tips may be due to the exosmosis of sugary substances as sections of mature tips show no breakdown of the hyphae composing them. It has been observed that the hyphae of the tips, both before and after the production of basidia and spores, are much more densely protoplasmic than those immediately beneath the hymenium on the branches, and than those composing the main substances of the plant.

This plant, as far as is known, is peculiar to Australia. It was first collected by Mr. E. J. Semmens, of the Creswick Forestry School, and was sent to Lloyd, who published the following description.

"*Clavaria capitata*—stems slightly sulcate, few branched. Branches terminating in sub-globose heads bearing the hymenium, spores 7–13–16 μ, if coloured, very pale, smooth, laterally apiculate at the base. Evidently grows on the ground. Colour, which Mr. Semmens says has not changed much, is the Isabelline colour that most white plants take on in drying, nothing distinctive. The idea of a Clavaria not having the hymenium over stems or branches, but confined to terminal heads, is a new one, I think, in Clavarias, hence could be made a new genus (*Capitoclavaria capitata*)."

Although Lloyd does not make it clear that he was describing a new species, no trace of an earlier description of a plant bearing this name can be found. In a letter, Mr. Semmens says that Mr. Lloyd did not mention at the time that it was a new species, but he, himself, had always understood it to be so. The identification of *Clavaria capitata* from Lloyd's description would be a difficult matter, but Mr. Semmens has given us a co-type specimen and this is identical with the plants I have described above. As the co-type (and further collections of the plant) show differences from Lloyd's description, the following amended description is put forward.

CLAVARIA CAPITATA Lloyd em. Fawcett.

Plantae ramosae et satis magnae, gregariae, emergentes in fascibus e massa mycelii humum colligantis. Trunca non manifesta, juxta terram se dividens, axiles acuti. Cacumina

primum sub-globosa, non-viscida, diende se dilatantia, interdum conjungentia in massam densam, nunc viscida et maxime differentia textura et colore ab ramis qui leves et non-viscidi sunt. Color cacuminum inter "Honey Yellow" et "Chamois," reliquarum partium praeter basis qui albus est "Maize Yellow" ad "Pale Orange Yellow." Caro alba, crispus et fragilis, sapor blandus.

Hymenium et ramos et cacumina tegit; postea in cacuminibus oritur. Basidia plurimum bispora, interdum quadrispora. Sporae 11–13 × 4.2–5 *μ*, *ellipsoideae cum apiculo obliquo prominenti, omnino asperae, ochraceae. Loc. Ararat* (*type*). *Kinglake, Tourrorrong, Healesville, Cockatoo.*

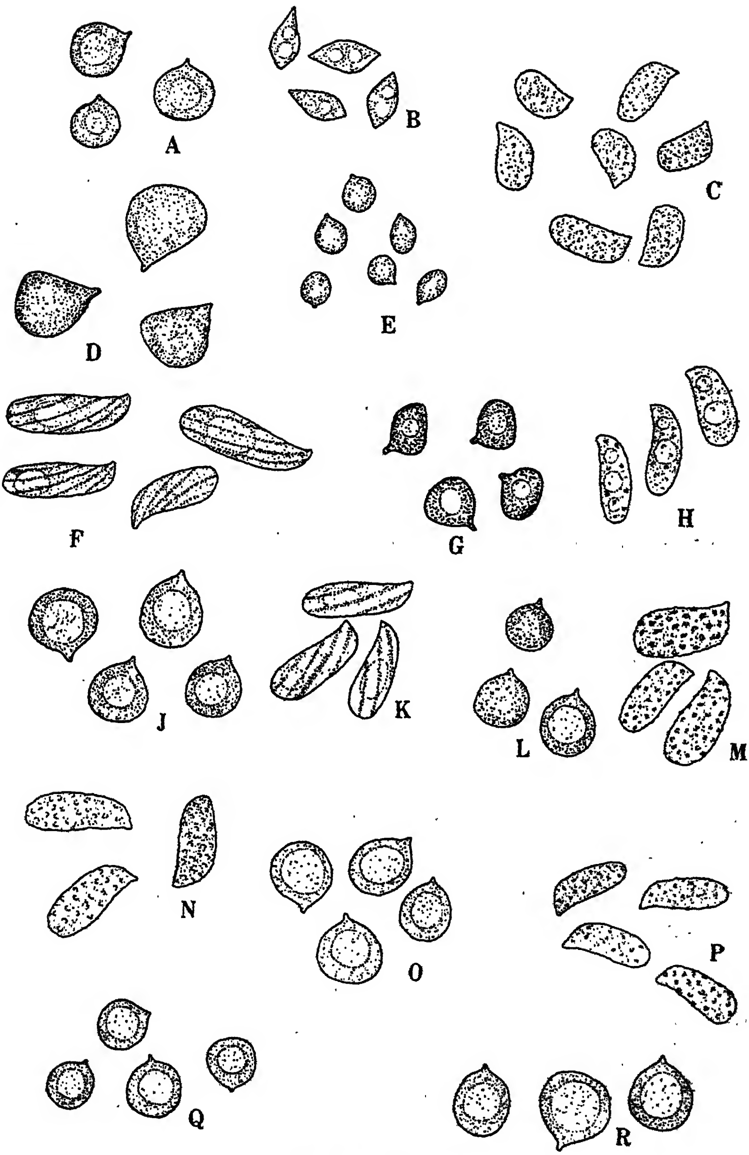
Clavaria capitata is a very well marked species and may be distinguished from all others by its pale yellow body and sharply contrasting sub-globose or expanded tips. *Clavaria ochraceo-salmonicolor* approaches rather close to this species in the possession of a number of sub-globose swellings at the tips but these do not differ in colour or texture from the rest of the plant.

Clavaria sanguinea Fr. ex Pers. Pers. Obs. Myc. 2: 61, pl. 3, fig. 5, 1799.

(Plate XXI., fig. 10, text fig. 1 (H).)

Plants stout and branched, up to 7 cm. high and 3–6 cm. broad. Branches arising from a short, stout stem which is pointed at the base and not deeply rooting. Main branches stout, arising near the ground level and continuing to the base as furrows. Many branches dividing irregularly to form very many small ones which branch once or twice again to form the ultimate tips which are blunt and with one or two blunt cusps. Colour, when young, pallid yellow, later deepening to Maize Yellow, base persistently whitish. Base and all other parts staining a deep reddish brown when handled. Flesh white, soft, only superficially staining red. Taste and odour, very faint. Spores ochraceous, slightly rough, elliptical, 9–11 × 3–4.5 μ with several small guttae and an obliquely terminal mucro. Growing on ground—Kinglake. Not previously recorded for Australia.

This is a distinct and well-marked species but there is some doubt as to its correct name. While otherwise similar to the plant Coker interprets as *C. sanguinea*, our plant has larger spores. Maire and Bresadola, among others, interpret plants which closely resemble ours in spore character, habit, and colour as *C. flava*. However, *C. flava*, as now understood, does not stain red on bruising, and in view of the fact that in all other characters, except size of spores, our plants and Coker's are similar, it seems best to disregard the discrepancy in spore size and call our plant *C. sanguinea.*



Clavaria Spores.

Spores of the following species:—(A) *C. aurantia;* (B) *C. corallino-rosacea;* (C) *C. sinapicolor;* (D) *C. acuta;* (E) *C. vermicularis;* (F) *C. rufescens;* (G) *C. pulchra;* (H) *C. sanguinea;* (J) *C. Miyabeana;* (K) *C. australiana* (co-type); (L) *C. fusiformis;* (M) *C. fennica;* (N) *C. capitata* (co-type material); (O) *C. luteostirpata* (type); (P) *C. botrytis;* (Q) *C. pallidorosea* (type); (R) *C. caepicolorosa* (type). Magnification 1125.

Explanation of Plates.

Unless otherwise stated, all photographs are natural size.

PLATE XVII.

FIG. 1.—*Clavaria capitata*, young plant showing unexpanded tips.

FIG. 2.—*C. capitata*, mature plant with expanded tips.

FIG. 3.—Vertical section of the end of a branch of a mature plant of *C. capitata*. Notice the recurved margins, fusion of adjoining tips, and totally enclosed pockets lined with the hymenium. The white lines represent the hymenium. Magnification 6 ×.

FIGS. 4 and 5.—*C. fusiformis*.

FIG. 6.—*C. capitata*. Aspect of young plant looked at from above.

PLATE XVIII.

FIG. 1.—*C. botrytis*, showing clustered habit, and undeveloped basal twiglets.

FIG. 2.—*C. fennica*. Portion of young plant. Notice knob-like rudiments of the branches.

FIG. 3.—Large plant of *C. botrytis*, showing elongated branches characteristic of mature and over-mature plants. Two-thirds natural size.

PLATE XIX.

FIG. 1.—*C. pulchra*.

FIG. 2.—*C. caepicolcrosa*. Mature plants. Notice well-defined stem.

FIGS. 3 and 4.—Young plants of *C. caepicolorosa*.

FIG. 5.—*C. luteostirpata*.

PLATE XX.

FIG. 1.—*C. rufescens*. One-half natural size.

FIG. 2.—*C. pallidorosea*.

FIG. 3.—Enlarged view of the tips of young plant of *C. capitata*. Notice the sharp difference in colour of the tips and the branches.

PLATE XXI.

FIG. 1.—*C. sinapicolor*. Typical large plant.

FIGS. 2, 3, 4, 5, 6, 7.—Small plants of *C. sinapicolor*, showing varying degrees of fusion.

FIG. 8.—Medium-sized plant of *C. sinapicolor* apparently derived from a large number of smaller ones.

FIG. 9.—Medium-sized single plants of *C. sinapicolor*.

FIG. 10.—*C. sanguinea*.

PLATE XXII.

FIG. 1.—*C. rufescens*, young plant.

FIG. 2.—*C. corallino-rosacea*.

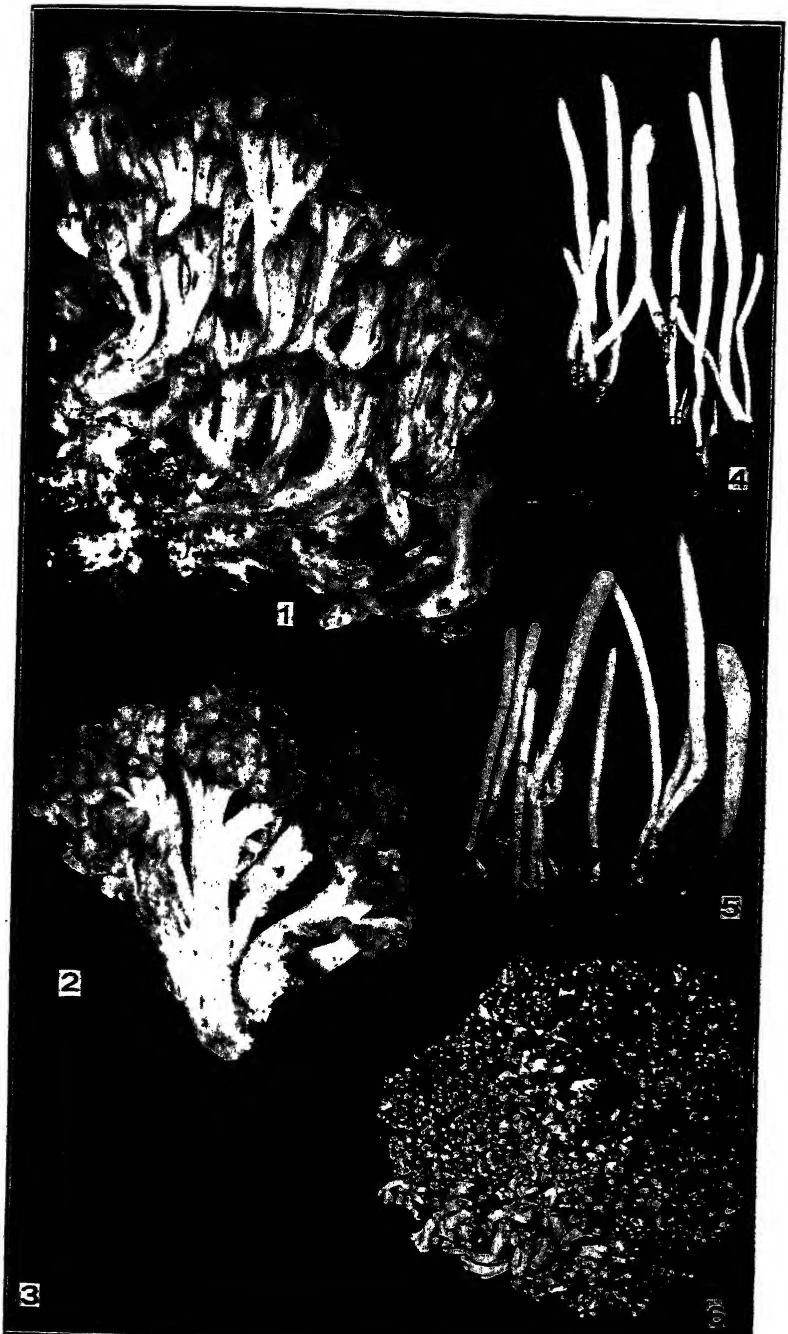
FIG. 3.—*C. aurantia*.

FIG. 4.—Young plant of *C. botrytis*. Notice the extremely stout base.

FIGS. 5 and 6.—*C. corallino-rosacea*, showing characteristically twisted plants.

PLATE XXIII.

C. Miyabeana.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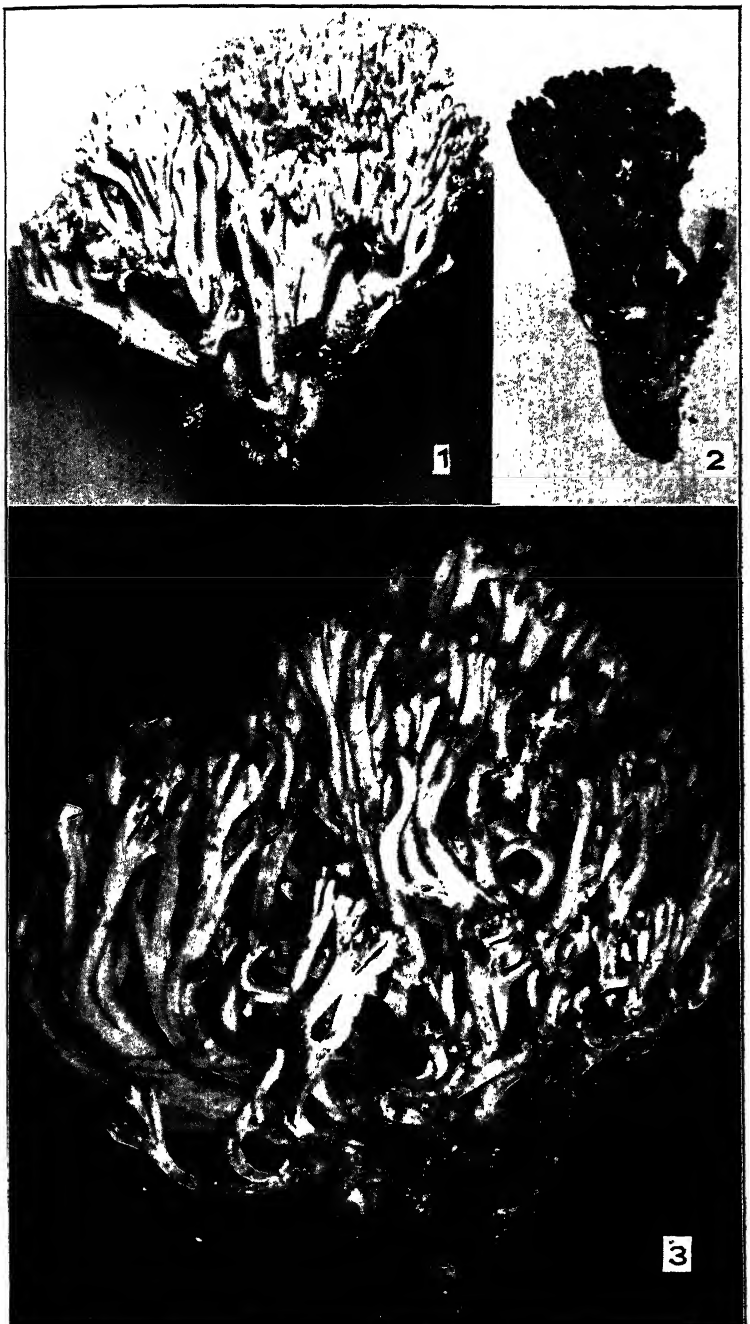
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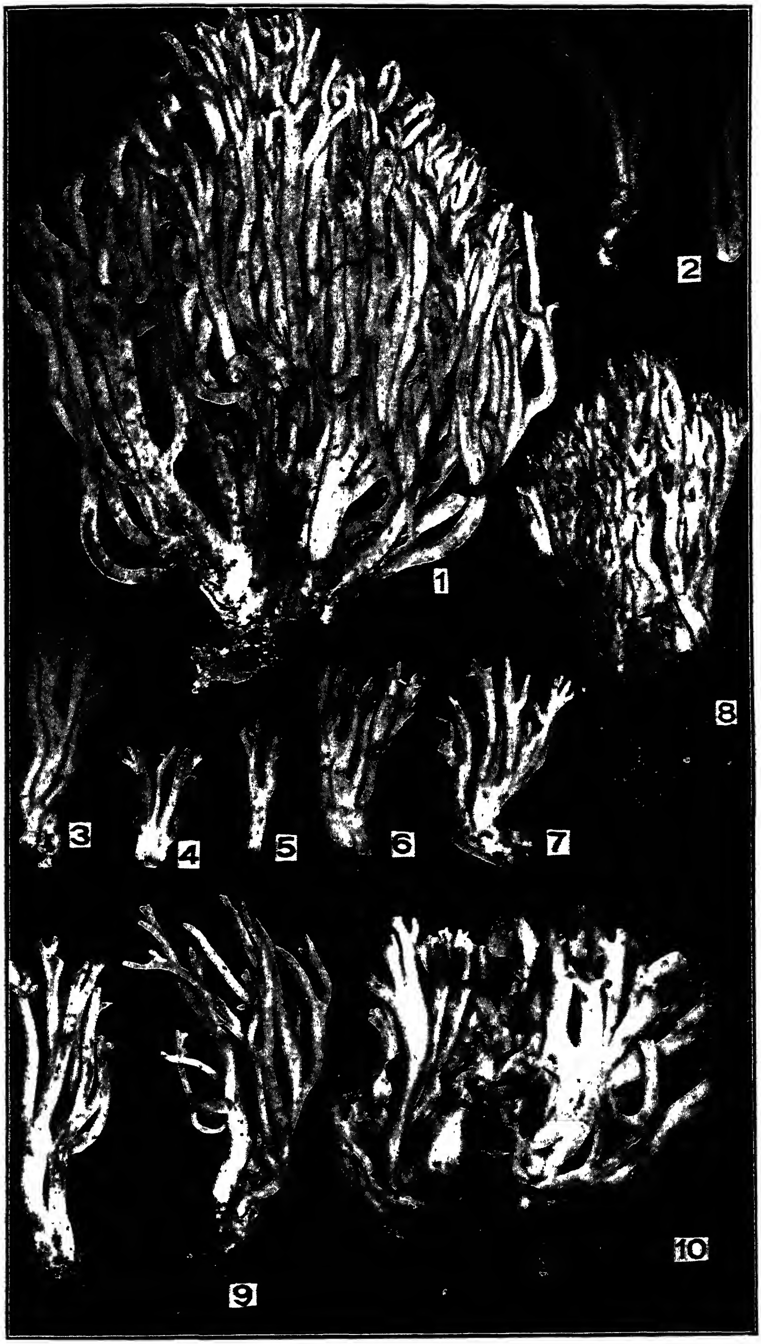
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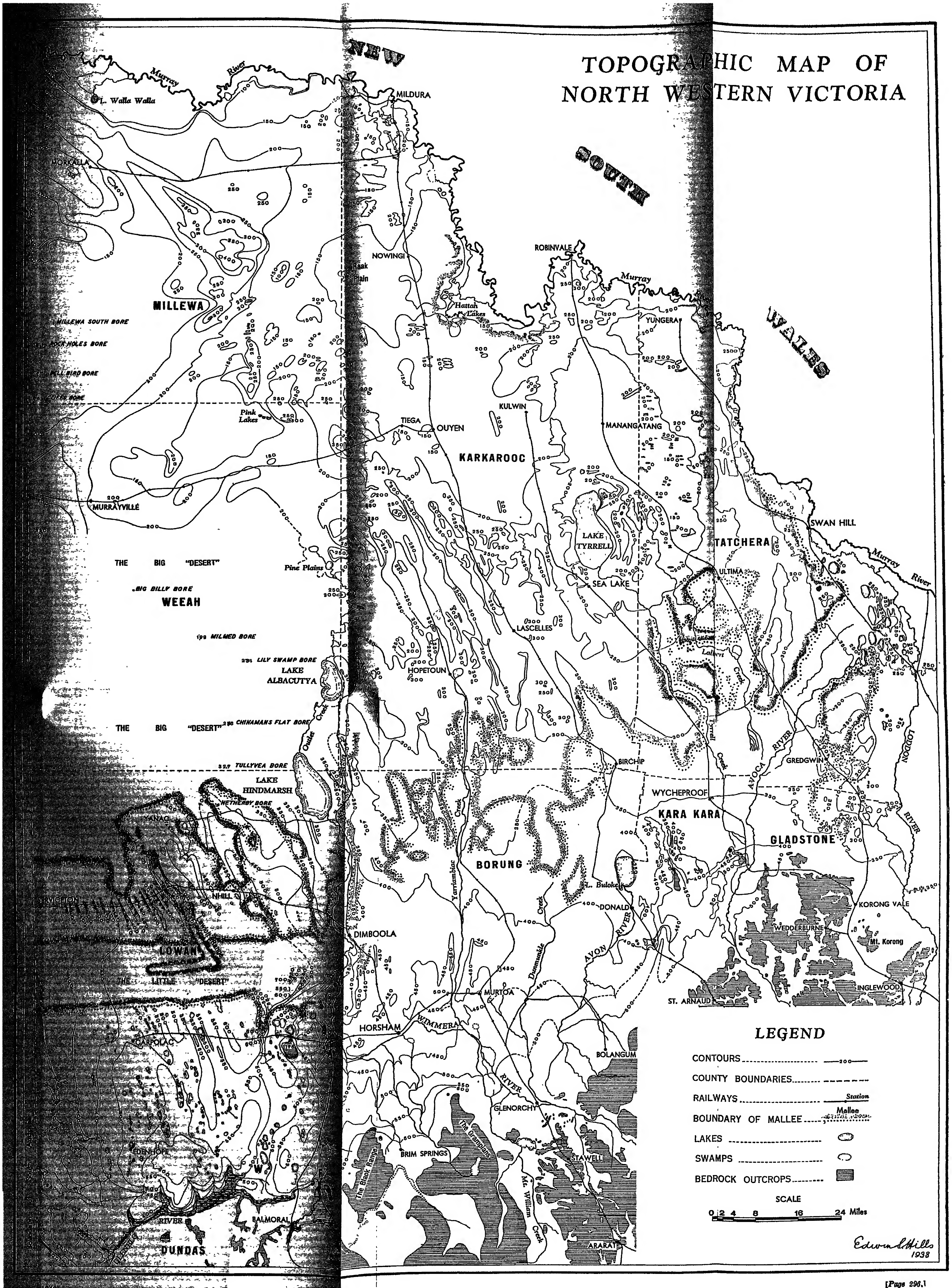
TOPOGRAPHIC MAP OF NORTH WESTERN VICTORIA
NEW SOUTH WALES
Murray River
L. Walla Walla
MILDURA
MORKALLA
MILLEWA
MILLEWA SOUTH BORE
NOWINGI
Hattah Lakes
ROBINVALE
YUNGERA
Pink Lakes
TIEGA
OUYEN
KULWIN
MANANGATANG
KARKAROOC
MURRAYVILLE
THE BIG "DESERT"
BIG BILLY BORE
WEEAH
MILMED BORE
LILY SWAMP BORE
LAKE ALBACUTYA
Pine Plains
LAKE TYRRELL
SEA LAKE
TATCHERA
SWAN HILL
ULTIMA
LASCELLES
HOPETOUN
CHINAMANS FLAT BORE
TULLYVEA BORE
LAKE HINDMARSH
HETHERBY BORE
BIRCHIP
GREDGWIN
WYCHEPROOF
KARA KARA
GLADSTONE
LODDON RIVER
AVOCA RIVER
Tyrrell Creek
Lalbert Creek
Outlet Creek
BORUNG
Yarriambiac Creek
L. Buloke
DONALD
AVON RIVER
Dunmunkle Creek
KORONG VALE
WEDDERBURNE
Mt. Korong
NHILL
DIMBOOLA
LOWAN
THE LITTLE "DESERT"
MURTOA
ST. ARNAUD
INGLEWOOD
HORSHAM
WIMMERA RIVER
CARPOLAC
BOLANGUM
GLENORCHY
The Grampians
The Black Range
BRIM SPRINGS
STAWELL
Mt. William Creek
EDENHOPE
BALMORAL
DUNDAS
ARARAT
LEGEND
CONTOURS 200
COUNTY BOUNDARIES
RAILWAYS Station
BOUNDARY OF MALLEE Mallee
LAKES
SWAMPS
BEDROCK OUTCROPS
SCALE
0 2 4 8 16 24 Miles
Edwin S. Hills 1938

[PROC. ROY. SOC. VICTORIA, 51 (N.S.), Pt. II., 1939.]

ART. XIII.—*The Physiography of North-Western Victoria.*

By EDWIN SHERBON HILLS, Ph.D., D.Sc.

[Read 8th December, 1938; issued separately, 24th July, 1939.]

Introduction.

In that portion of the Murray Basin Plains which lies within Victoria, two major physiographic divisions may be recognized, the boundary between them being the Loddon River or, more precisely, the western edge of the Loddon flood plain. The Loddon and the streams to the east of it that cross the plains of the Northern District join the Murray, but west of the Loddon streams from the Highlands fail to reach the Murray and usually terminate in shallow lakes. Thus, between the terminations of these streams and the Murray there is an area from which flowing streams are absent. It is the western section of the Murray Basin Plains, from the Loddon River to the boundary of South Australia, and from the edge of the Western Highlands to the Murray River, that forms the subject of this paper. Within the area dealt with are included the Victorian Mallee, the Wimmera country, and portion of the Murray Valley.

It gives me very great pleasure to acknowledge the help I have received during the preparation of this paper, from officers of the State Rivers and Water Supply Commission, the Geological Survey, the Railways Department, the Forestry Commission, the Lands Department, and the Country Roads Board. For information concerning the Mallee, I am especially indebted to Mr. R. F. McNab, Divisional Engineer of Water Supply for the Mallee and Wimmera, whose co-operation was essential for the preparation of the topographic map (fig. 1). I am also indebted to Mr. W. Baragwanath, Director of the Geological Survey of Victoria, for the permission to use information in an unpublished Bulletin on copi deposits by Mr. S. B. Abbot, for facilities placed at my disposal in the Mines Department, and much help in other ways. Mr. A. S. Kenyon has also very kindly discussed many problems with me, and allowed me to draw freely on his unique knowledge of the Mallee. To Mr. P. Cresswell, Secretary of the Shire of Lowan, I am obliged for information concerning bores and wells near Nhill, and to Mr. W. J. Zimmer, chief forester for the Mildura district, for help in the delimitation of the Murray Valley in the far north-west.

Topography.

A topographic map of the area under consideration, showing contours at 50-ft. intervals, is given as fig. 1. This map was constructed from all available sources of information, but is largely based on data supplied by the State Rivers and Water Supply Commission and the Geological Survey, and on trial railway surveys. In Co. Lowan data were also obtained by aneroid.

The most obvious feature brought out by the map, and one that differentiates the area from the plains east of the Loddon, is the existence of well-marked ridges and troughs whose trend varies from north-west to east of north. East of the Loddon, on the other hand, the main contour lines run east-west, and there are extensive tracts of country which are almost perfect plains, sloping at a rate of 5 feet in 1–2 miles towards the Murray. The existence of relatively strong topographic features west of the Loddon has important consequences in regard to the lay-out of irrigation channels, and some of the main ridges are already distinguished by name by the officers of the Water Supply Commission (see fig. 2). The easternmost ridge is that on which Cannie township is situated, and is known as the Cannie Ridge. South-east of this ridge is an area of high land around Gredgwin. The next ridge to the west runs north-south through Robinvale and Annuello, and continues southwards, with a break east of Kulwin, along the western side of Lake Tyrrell. It is known as the Tyrrell Ridge. Further to the west is a series of ridges and troughs which is best exhibited in the southern portion of Co. Karkarooc, but which continues north-westerly, with one intervening strip of low land, and develops into a well defined ridge at Walpeup (350 feet). There the ridge is referred to as the Walpeup Ridge, and its southerly continuation is known as the Denying Ridge. It is broken in the north by an extensive low area, but on the same line is a very well marked ridge in Co. Millewa, trending north-west and extending into South Australia. This may be termed the Millewa Ridge. Extending south from Mildura to beyond Red Cliffs is a minor ridge which is economically important in that it cannot receive water by gravitation from the main Mallee water channels, and necessitates pumping from the Murray. This may be termed the Red Cliffs Ridge. In Co. Lowan, the ridges trend N.N.W.–S.S.E., but, although very well marked in the field, they are not comparable in size with the main ridges above referred to, and are probably also of different origin. d'Alton (1913) has named the most prominent of these Lowan ridges, which rises to 650 feet above sea level between Diapur and Miram, the Lawloit Range.

In contrast with the ridges there are certain broad topographic basins, and also extensive flood plains formed by the larger streams. One of the largest basins is that in which the Lake

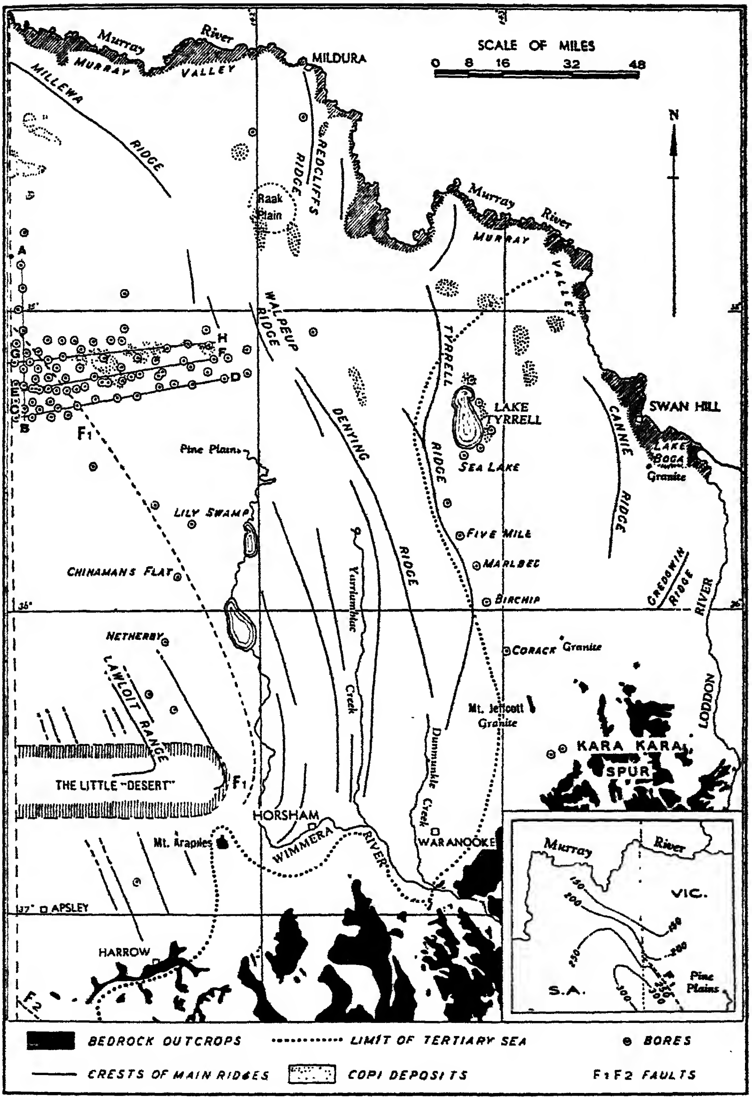

Fig. 2.—Map showing the chief structural features of North-Western Victoria. (NOTE.—For Kara Kara Spur read Gladstone Spur.)

Tyrrell–Lake Wahpool group of lakes is situated. It may be termed the Tyrrell Basin. This basin is bounded on the east by the northerly continuation of the Cannie Ridge, which swings round the northern edge of the basin to join the Tyrrell Ridge. The latter forms the western edge of the basin. Another important area of low land is that which separates the Walpeup Ridge from the Millewa Ridge. Within it lies the Raak Plain and an extensive system of shallow salt lakes in the northern part of Co. Karkarooc. This low area may be termed the Raak Basin. The boundary of South Australia crosses two other basins, near Cow Camp and Cudmore's Tank respectively, in Co. Millewa.

All the above-mentioned ridges and basins are of large dimensions, and are entirely distinct in origin from the small ridges and intervening troughs resulting from aeolian sand drift. The sand ridges have a general trend slightly north of east and south of west, and rarely rise as much as 50 feet above the general level of the country (see fig. 7). As well as the east-west sand ridges there are, on the eastern sides of nearly all the small lakes and on many of the swamps, crescentic ridges of sand or loam. The latter may be seen to perfection around the lakes between Kerang and Swan Hill, and they appear to be unique land forms, as I can find no reference to the occurrence of similar features in other parts of the world. They were commented upon first by Major Mitchell, who was so struck with their peculiarities that he devoted many pages to their description (Mitchell, 1839).

General Geology.

The area constitutes portion of the ancient Murray Gulf (Gregory, 1903). Such bores as have been carried down to bedrock have bottomed on various rock types, as follows (see Jack, Stirling, and Checchi, 1897; for location of bores see figs. 1 and 2, and Kenyon, 1914) :—

Netherby: Sandstones, shales, and conglomerates at 978-2,175 feet; porphyry between 2,175 feet and 2,200 feet.
Chinaman's Flat: Clay shale, probably bedrock at 1,473 feet.
Lily Swamp: Green shale taken as bedrock, at 1,080 feet.
Corack: ? Silurian at 270 feet.
Birchip: Metamorphic rock at 760 feet.
Marlbed: "Blue" rock, 863-899 feet, then granite or micaceous sandstone.
Five Mile: Quartz, clay shales, etc., at 810 feet.
Sea Lake: Kaolin, quartz, etc., at 828-1,076 feet, then shale with quartz.
Lake Boga: Granite at 200 feet.

The records of metamorphic rocks at Birchip and quartz veins at Sea Lake, with possible granite at Marlbed, show that, in the series of bores running north from Birchip, the bedrock is probably similar to the exposed Palaeozoic rocks on the northern edge of the Western Highlands, where metamorphic

rocks, granites, and reef quartz occur. The prevalence of granitic monadnocks in the area between Lake Boga, Wycheproof, and Wooroonook, and at Mt. Hope and Pyramid Hill to the east, suggests that much of the eastern part of the district is probably underlain by this rock.

Marine Tertiary rocks are restricted to the western portion of the area (see fig. 2). East of the marine incursion the bedrock basin was filled mainly with a continental series of ligneous clays, fluviatile and lacustrine sands, gravels, and gypsum, with possibly some estuarine deposits. In the area where marine deposits occur, ligneous clays of continental and shallow marine origin are overlain by Miocene limestones, and these in turn by marine Pliocene shell marls and glauconitic sands, and by later deposits. According to Chapman (1916), marine strata of Upper and Lower Pleistocene age occur in some of the bores in the northern parts of Co. Weeah. The Pleistocene and Recent deposits are, however, dominantly lacustrine, fluviatile, and aeolian in origin.

The Origin of the Major Topographic Features.

The Ridges and Dry Valleys of County Lowan.

Two previous authors (Dennant, 1886; Fenner, 1918) have referred to the origin of these features. Dennant, noting the universal sandy nature of the soils on the ridges, the presence of sandstones at "Mortat" (now Goroke) and Kadnook, and the fact that the strike of the ridges is parallel to that of the chief sandstone ranges in the Grampians, considered them to represent Grampians sandstones partially buried by Tertiary deposits. Fenner, in discussing the physiography of the Glenelg, concluded that the valleys, many of which are occupied by lines of swamps, represent old river courses. These two interpretations are not incompatible, and Dennant has also remarked that the lines of swamps probably represent old stream courses, desiccated by climatic changes. He remarks that, after heavy rain, Lake Wallace drains to the Booroopki Swamp, 26 miles to the north, by means of an actual current.

Concerning the ridges, it is true that relatively hard sandstones underlie the surface sand in all of them that I have examined. These sandstones are red or mottled, and in places develop a very hard ironstone capping. They occur in sandy patches near Nhill, where they are extensively quarried for use as a road metal, in the Lawloit Range, where they outcrop at the surface, in the Little "Desert," at Goroke, and at Kadnook, and there can be little doubt that the majority, if not all, of the ridges with poor sandy soils that occur in Co. Lowan are composed of this rock. The presence of these sandstones in the Little "Desert" explains in part the existence of this feature, although, from aneroid levels, it would appear that the "Desert," near its

western end, is not a well marked ridge. However, d'Alton (1913), who traversed the eastern part of the "Desert," shows a sandstone ridge running east-west through it, and terminating east of the Kaniva-Goroke road. This indicates that the origin of the "Desert" is essentially similar to that of the sandy N.N.W. trending ridges, its existence being determined by the nature of the soils derived from the sandstones which occur in it.

Petrologically, the dominantly red sandstones of which the ridges are composed are quite unlike the typical Grampians sandstones, especially in their high iron content and the lack of a siliceous cement. Furthermore, wherever the bedding could be observed, the sandstones of the Lowan ridges are flat-lying, whereas the majority of the Grampians beds are dipping at high angles. It is much more probable that the sandstones are Tertiary in age.

Late Cainozoic Warping in County Dundas and County Lowan.

As pointed out by Fenner, a divide was formed in late Cainozoic times by warping about an east-west axis running through the highlands of Co. Dundas. At the present time the northern part of this county, which is drained by tributaries to the Glenelg and the Wannon, affords an excellent example of a warped plain, dissected to the stage of late youth. Between the streams, remnants of the plain are preserved in many places, and a north-south traverse shows clearly, by the alignment of the summits of these remnants, both the northerly and the southerly or south-westerly slopes, on either side of the warp axis (Pl. xxiv., fig. 1). This warped and dissected plain consists of Cainozoic sandstones, sands, quartz gravels, and ironstone gravels, overlying Jurassic sandstones, granites, Cainozoic lavas, and other rocks. The ages of the Cainozoic rocks are uncertain. At Harrow, fossils indicate the presence of Miocene beds, but it is probable that the surface of the plain was developed long after this date, for the ironstone gravels have the appearance of buckshot gravel; they are very widely distributed, and may represent a fossil soil horizon. Support for this is also given by the fact that dips observed in Cainozoic sands between Casterton and the Hummocks show that the surface of the dissected plain is not parallel to the dip in these sands, whereas the ironstone gravels, where observed by me, are parallel to the surface of the old plain and give rise to the steep escarpments that occur around the remnants of it. Furthermore, the presence of the Murray River tortoise *Eurydura macquariae* (Gray), at Carapook (Chapman, 1919), indicates that at some recent date communication by a dominantly fresh-water route was possible between the northern and southern streams. The suggestion is that the ironstone cappings on the Dundas Highlands were developed as soil horizons or as deposits in swamps or lakes during late Cainozoic times, and that the uplift of these Highlands is therefore of fairly recent date.

The slope of the warped plain from the axis in Co. Dundas continues north across the Gleenlg into Co. Lowan, and there can be little doubt that before the dissection south of the Glenelg was carried very far, north-flowing streams ran into Co. Lowan. These streams dissected the Tertiary cover of the plain, and cut well-defined valleys which were later abandoned. The causes of this abandonment will be discussed later (p. 308). This suggestion affords an explanation of the existence of the dry valleys running north from Fulham and from the White Lakes F and W, fig. 1), but there are difficulties in applying it to the ridges and valleys further west near Edenhope, and those north of the Little "Desert" between Kaniva and Serviceton. These features are remarkably straight and parallel, and they are not continuous from north to south but are broken by the Little "Desert" and by other sandy patches of high ground (see figs. 1 and 2).

In elucidating the origin of these ridges and valleys, it is important to know whether the red sandstone of the ridges occurs beneath the heavy soils and clays of the valleys, or whether the valleys have been cut through a formerly continuous sandstone capping, leaving the ridges as remnants. Wells and bores, after passing through the superficial soils, come first upon loam and clay, then 10 to 30 feet of red sandstone, hard in places, and then enter marine limestones probably of Miocene or Lower Pliocene age. It appears, therefore, that as is suggested by the discontinuity of the valleys, the ridges represent open anticlines in which the red sandstones are brought to the surface, and that in the intervening synclines the overlying clays are preserved (see fig. 3). The water table developed above these clays intersects the ground surface in winter, causing the swamps, which dry up in summer as the water table is lowered owing to the low rainfall and high evaporation.

It appears to me to be improbable that these folds should be due to lateral compression acting on the Cainozoic rocks, for these are less than 1,000 feet thick in Co. Lowan, and no

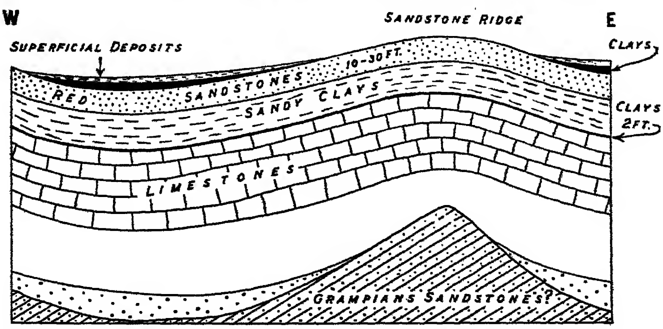

Fig. 3.—Cross-section showing the probable geological structure in Co. Lowan. Approximate horizontal scale, 1 in. = 2 miles; vertical distances not to scale.

mechanism for the transmission of the compressive forces can be suggested. The close spacing of the ridges, their parallelism and symmetrical cross section are against the idea that they were caused by faulting in the bedrock, and I would suggest that they reflect a buried topography, consisting of regular, steep ridges in some places, and more rounded hills in others. The proximity of the Grampians, and the presence of an outlying patch of Grampians sandstones at Mt. Arapiles, indicates that perhaps the regular and parallel surface ridges overlie buried strike ridges of Grampians sandstones, and that the sharp curvature to the west of the Lawloit Range reflects the presence of a buried "nose" of a pitching fold in these rocks. The trend of the ridges is parallel to the general strike in the Grampians, and also to the ridge running southwards from Mt. Arapiles.

Major Topographic Features of the Mallee.

Major topographic features in a region such as north-western Victoria, where a cover of relatively soft Cainozoic rocks overlies a resistant basement complex, can be formed in several ways, the chief of which are (1) faulting and folding due to diastrophic forces acting on the covering rocks themselves, (2) by movements in the basement complex which are transmitted to the overlying strata, or (3) by differential compaction, which causes buried topographic features to be reflected in the rocks that cover them. In all these instances the surface topography is paralleled to some extent by the structures of the rocks covering the basement complex—structural anticlines are ridges at the surface, and so on. On the other hand, topographic features due to erosion are not directly reflected in the structures of the underlying rocks. Thus, in interpreting the topography of the Mallee, it is first of all necessary to discover how far surface features are represented in the structures of the Cainozoic rocks of the ancient Murray Gulf.

The only portion of the Mallee where the Cainozoic geology is known in sufficient detail for our present purposes is in the northern portion of Co. Weeah, where the artesian and sub-artesian water in the Miocene limestones is tapped by numerous bores. In boring for water in the Mallee, the bores are usually carried down to a particular geological horizon near the top of the Miocene limestones. The bore records are therefore susceptible of geological interpretation in a broad way, and sections along the lines AB, CD, EF, and GH in fig. 2 have been constructed on the assumption that the figure for "depth to fresh water struck," given for each bore (see Kenyon, 1914), indicates the depth to a particular geological horizon. This method was suggested to me by Mr. McNab, and Chapman's interpretation of the Murrayville bores indicates

that it is likely to be sufficiently accurate to give some idea of the geological structure, though I am informed by Mr. A. S. Kenyon that the same bed is not tapped in each bore. In addition, a geological section (fig. 4), based on the data given by Chapman (1916) and on unpublished sections by Mr. A. S. Kenyon that were kindly placed at my disposal by Mr. L. R. East, Chairman of the State Rivers and Water Supply Commission, has been drawn along the line of bores studied by Chapman. The structure revealed in this section is paralleled in those along the lines above referred to, indicating the validity of the method used in their construction.

It is immediately clear from the sections that the surface features in northern Weeah are reflected in the structure of the Cainozoic rocks. In particular, the rise to the high area near the South Australian border, south of Panitya, is well brought out (see fig. 4). Howchin (1929) has already recognized the

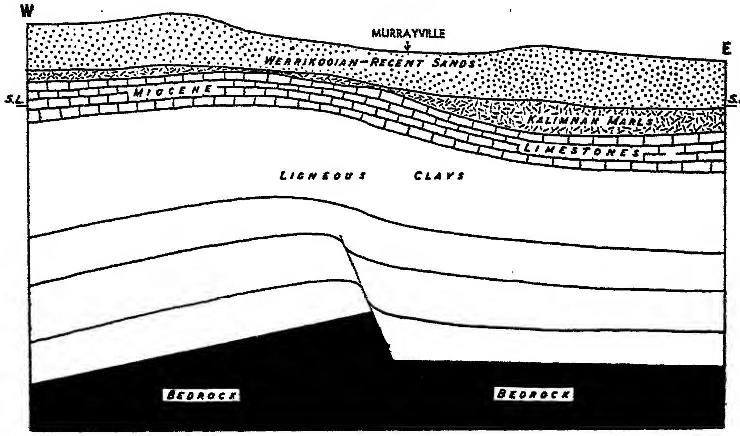

Fig. 4.—Geological section in the north of Co. Weeah, illustrating the probable relationship of warping in the Cainozoic rocks to faulting in the bedrock. Nature of bedrock unknown. Vertical scale for upper part of section, 1 inch = 600 feet; horizontal scale, 1 inch = 5 miles. Total thickness of Cainozoic rocks diagrammatic.

tectonic origin of the corresponding area of high land around Pinnaroo in South Australia, basing his conclusions on the elevation of the superficial alluvial deposits, which must have been deposited when the area was at a lower level, and have been raised to their present position by recent earth movements. Howchin's work, moreover, makes it clear that the structural features were not developed as a result of differential compaction in the Tertiaries over bedrock ridges and troughs, for this process would have operated during the deposition of these rocks. It would have caused the development of a ridge in the Miocene limestones and Kalimnan marls, which would have prevented the deposition of the superficial Pleistocene and Recent alluvium that actually occurs on the summit of the high land.

The marked warp on the north-east side of the high area south of Panitya can be traced from the bore records, and is shown in fig. 2 as F1. In South Australia the high land west of this structure can be outlined by form lines constructed from railway elevations (see Insert, fig. 2). It is also shown in Jack's sections (1930). The high land trends north-westerly towards the Great Pyap Bend in the Murray, and appears to have been responsible for turning the river towards the north-west at the bend. In Victoria such elevations as are available in the Big "Desert" indicate a continuation of the structural line to the south-east, with low land on the eastern side, and it may continue further south, for the land west of the Wimmera River is, on the average, higher in elevation than that on the east. West of Dimboola the Wimmera turns northwards away from the high land which blocks its exit to the west. The probable origin of the warping in the Cainozoic rocks near Murrayville is suggested in fig. 4. As noted in connection with the Lowan ridges, it is difficult to conceive a mechanism capable of folding these rocks by lateral compression, and since, as above noted, differential compaction over buried bedrock is excluded owing to the existence of fluviatile and lacustrine deposits on the up-warped western side, it appears to be most probable that the warp at the surface reflects a fault in the bedrock beneath the Cainozoic cover. The greater thickness of Kalimnan marls on the down-warped side indicates that the structure was partially formed before these rocks were laid down, but was completely covered by them, and then subjected to a later movement, warping the Kalimnan and the overlying, younger deposits.

It is still possible that other factors may have operated to produce the ridges and troughs in other parts of the Mallee and in the Wimmera. A clue to the possible effects of differential compaction over buried bedrock ridges, for instance, can be obtained by noting the relationship of the ridges of the plains to spurs running out from the highlands. Two spurs that are particularly instructive are, firstly, that on which Mt. Jeffcott, near Wooroonook, is situated, and that between Donald and Buckrabanyule. The latter is sharply truncated in the north at the 400-ft. contour, and the former at the 350-ft. contour. The Mt. Jeffcott ridge is on the same trend line as the summit of the Tyrrell Ridge, north-west of Birchip, but this latter ridge swings to the south and passes to the west of Birchip, so that it appears to be unrelated to the Mt. Jeffcott ridge. Furthermore, those inliers of bedrock that occur in the plains, as in Wycheproof and south of Lake Boga township, are not situated on the main ridges. Mt. Wycheproof, a low granitic hill, rises like an island from the surrounding plains, and the Lake Boga granite occurs as a low hill, indistinguishable topographically from those surrounding it, which are presumably composed of Cainozoic sediments. The summit of the Cannie Ridge lies well to the

west of this granite outcrop. Near Glenorchy and also south of Mysia, small hills of bedrock rise from the plains. Here again the bedrock outcrops are unrelated to the main ridges. It would appear, therefore, that differential compaction of the Tertiaries over bedrock ridges and valleys has not been an important factor in determining the major topographic features of the north-western plains, although it may have affected the topography in Co. Lowan, as above noted.

It is significant that the ridges, troughs, and basins in the Mallee are, with the exception of the complex ridges and valleys in Co. Karkarooc, large-scale features. The ridges are of the order of eight miles across, and the Tyrrell Basin is approximately thirty miles from east to west and fifty miles from north to south. It is clear from this fact alone that erosion is inadequate to explain them. As indicated above, lateral compression is also difficult to invoke, but it may be applicable to the Karkarooc ridges, where compressive forces possibly developed as a result to squeezing between F1 (see fig. 2) and a possible fault or major warp beneath the Tyrrell Ridge.

Most of the major ridges are, I believe, due to warping and faulting in the basement complex. Such movements are known to have occurred in connection with the warping in Co. Dundas, and also in the Echuca district (Harris, 1938), near Murrayville as described above, and near Casterton. At the latter locality, a N.W.–S.E. trending fault (F2, fig. 2) exposes Miocene limestones on the scarp. This fault is a continuation of the northern fault (F2) shown by Fenner (1931, p. 60) in south-eastern South Australia. Warping and faulting have also occurred in the Western Highlands. Where the cover of Cainozoic rocks is thin, an indication of upwarping would be given by the stripping off of this cover and the exposure of the bedrock as a major "spur" running north from the Highlands. The Gladstone "spur" (Gregory, 1903), which extends north from Wedderburne (fig. 2), appears to represent such an upwarped region. The low granitic plateau which surrounds the higher slopes of Mt. Korong may be regarded as a stream-planed pediment developed by laterally eroding streams before uplift occurred. Upon elevation of the region this erosion surface would be preserved on the resistant granites, but removed where it was cut in the surrounding metamorphic and sedimentary rocks. It is notable that the Cannie Ridge and the Gredgwin Ridge are in line with the Gladstone "Spur," and they probably represent similar and perhaps related upwarpings in the bedrock.

The Evolution of the Drainage System.

The present drainage system of the area is quite distinct from the normal arrangement of streams in regions of pluvial climate. In the Highlands to the south the stream pattern is dendritic, but

where the streams enter their plain tracts they develop anastamosing anabranches, and some of the main north-flowing streams, e.g., the Yarriambiac Creek, Dunmunkle Creek, Tyrrell Creek, and Lalbert Creek, are effluents from the Wimmera and the Avoca Rivers. After taking their origin from the parent stream, either by a single channel or a number of minor channels, these effluents receive no tributaries, and, owing to evaporation and downward percolation, gradually diminish in flow to the north. With this diminution in volume downstream, the flow ultimately becomes so reduced that small topographic basins into which the streams flow are sufficient to hold the water normally available. Thus, all the streams flowing to the north, except the Dunmunkle Creek, terminate in shallow lakes.

The Glenelg System.

In his paper on the Glenelg, Fenner has suggested that the present course of this stream above Dergholm is the result of numerous river captures, whereby the headwaters of the former Glenelg captured streams which previously ran north from the divide in Co. Dundas, leaving at Brim Springs (Brimpaen Station) and Fulham, sharp elbows of capture. The topographic map lends strong support to the idea that a stream formerly ran northwards from the elbow at Fulham, and that another north-flowing stream occupied the valley in which the White Lakes are now situated. Near Fulham a broad valley extends northward from the elbow in the Glenelg, as shown by the 550-ft. contour. In the valley are numerous swamps (e.g., Barton Swamp), and its western edge falls steeply away from the plains around Kanagulk in a manner reminiscent of the Wimmera valley at Horsham. Below the elbow at Fulham, and also for some miles above it, the Glenelg is incised below the level of the north-trending valley. The valley containing the White Lake has a similar relation to that of the Glenelg. These relationships strongly suggest that river capture has taken place, but the present condition may also have arisen by other means.

It is possible that these dry valleys were formerly occupied by effluents from the Glenelg, before rejuvenation caused that stream to cut down to such a depth that effluents could not leave it. The former condition may have resembled that of the Wimmera at present. This stream, after leaving the Highlands, flows to the west and gives off the Dunmunkle and Yarriambiac Creeks. Rejuvenation of such a system would cause the main stream to cut down much more rapidly than the effluents, which would ultimately be left as dry valleys, when they could no longer be fed by the waters of the main streams during floods.

A difficulty in interpreting the changes as due to capture is to account for the headward erosion of the Glenelg around the western end of the Dundas Highlands, for the streams north

of the divide would have been, at least in their headwater regions, actively eroding, and would have cut down below the level of the headwaters of the streams flowing south. It is conceivable that the Glenelg flowed, *a priori,* from the north side of the Dundas divide, and it may then either have enlarged its former headwater region by capture, or have lost effluents in the manner outlined above.

At Brim Springs, where Fenner again postulates river capture, neither of the above processes appears to me to have taken place. The Glenelg, for some distance above and below the bend at Brim Springs, follows a very shallow, wide, swampy course which during dry weather is so unlike the valley of a stream that it can be crossed unwittingly. There is no gorge below the elbow, which indicates that capture has not occurred. A possibility is that, with such a weak stream, a slight warp across its course may have diverted it from a northerly course through the gap at Brim Springs and turned it south-westerly. This would also explain the swampy nature of this reach of the river, but on the actual divide at Brim Springs, solid Tertiary sandstone occurs, and river gravels, sands, and silts are absent. Thus, it appears more probable that no stream has flowed north through the Brim Springs gap since the initiation of the present drainage system, and that, with further aggradation in the swampy Glenelg at this locality, the river might even raise its bed the necessary 40 feet to overtop the low divide between it and the northern streams, and so flow out to the north.

The Wimmera.

Before the above changes in the Glenelg system took place, the Wimmera must have received at least one, and probably two, important tributaries from the south-west. The valley leading from the Glenelg at Fulham trends towards the Wimmera, and the White Lakes valley leads towards the lakes around Mitre, whence the waters of the former stream could have reached the Wimmera below Natimuk. Thus, the lower reaches of the Wimmera must have shrunk considerably in volume as a result of drainage modification, apart from any possible effects of climatic desiccation. It is interesting to note, therefore, that north of Pine Plains, which is the furthest north that the Wimmera waters have been known to reach (Kenyon, 1914-15), such topographic data as are available indicate a continuation of the main valley towards the north, with a lateral outlet south of Walpeup. The main valley leads north-westerly into a basin north of the railway line between Underbool and Cowangie, which is cut off from outlet to the west and north by higher land. As shown above, this high land is of quite recent tectonic origin, and Howchin has shown that corresponding high land around Pinnaroo was formerly occupied by lakes and traversed by rivers. To the north and north-east,

outlets from the extension of the Wimmera valley are also indicated by areas below 150 feet or even 100 feet, as at Rocket Lake and the Raak Plain. Between these low areas and the Murray, however, the lowest levels are above 100 feet, and if a former outlet of Wimmera waters took place through the Hattah Lakes or near Nowingi, earth movements must subsequently have reversed the slopes.

Copi Deposits.

In connection with the former condition of the north-western Mallee, the distribution of gypsum (copi) deposits is instructive (see maps, figs. 1 and 2). It will be noted that the main areas of copi are situated in the existing topographic basins. In many of these areas copi is not now forming. The restriction of copi deposits, in the main, to topographic basins, and the fact that it is forming to-day only in salt lakes, as in the Raak Basin and Lake Tyrrell, indicates that the copi deposits in Co. Weeah and Co. Millewa were laid down in former lakes. Chapman (1936) has demonstrated the existence of lacustrine ostracodal limestone in one of the main areas where copi occurs, around Bennett's Tank and Cudmore's Tank in north-western Millewa. Thus, there can be little doubt that lakes formerly existed in the main topographic basins in the far north-west of Victoria. In South Australia it has already been shown that uplift west of Overland Corner caused a lake system to develop upstream from the fault (Tate, 1885; Howchin, 1929). The former lakes of the north-west of Victoria are also undoubtedly due to modifications of former courses of the Wimmera and Murray, resulting from earth movements.

An idea of the conditions that existed in these lake basins can be obtained by analogy with similar basins in regions that are still supplied with water, e.g., the Tyrrell Basin. Here, radial centripetal consequent streams, the Tyrrell Creek and Lalbert Creek, both effluents of the Avoca which skirts the edge of the basin, flow during floods towards the centre of the basin, and supply water to the shallow lakes situated there. The bed of Lake Tyrrell, which is only a foot or so deep in normal seasons, is composed of fine mud in which gypsum crystals are embedded. Salt is also obtained from the lake during the dry season.

The lake itself is bounded by steep banks, 20 or 30 feet high on the western side, and it is possible that the actual lake basin was initiated as a result of the solution of underlying beds of gypsum, deposited during an earlier stage of the infilling of the Murray Basin. Evidence for the presence of soluble beds beneath the surface is afforded by sink holes that occur near the north-east side of the lake, and by the record of 233 feet of gypsum in the Marlbed bore (Jack *et alia*, 1897). Of recent years, deep gullying has occurred on the slopes leading to the

lake, and in these the sediments exposed are gypseous sands, well bedded and even laminated in places, which are evidently lacustrine deposits. These now have a gentle dip towards the lake, indicating that the present lake basin is a sagged area. The suggestion is that the now dry copi basins in the far north-west formerly resembled the Tyrrell Basin, but are now dry because of the reduction in the flow of the Wimmera consequent upon the capture of some of its tributaries by the Glenelg, and of the drainage of lakes formerly filled by Murray waters, as that stream cut its gorge below Overland Corner. Increasing aridity is a possible further contributing factor.

The Yarriambiac Creek.

This stream, which is an effluent of the Wimmera, presents some peculiar features. After leaving the Wimmera in a normal fashion as an overflow channel on a flood plain, it passes into higher country to the south, and at Jung enters a trough bounded on either side by a ridge. The ridge on the west rises to 500 feet at Jung township. This condition is quite abnormal for an effluent stream, which normally should flow over a flood plain throughout its whole course. A further notable feature of the Yarriambiac Creek is its straightness. Both these peculiarities indicate that below Jung the Yarriambiac is probably a longitudinal consequent stream occupying a synclinal valley, and bounded on either side by anticlines. South of Jung the ends of the ridges have been truncated by lateral plantation due to the swinging of the Wimmera over its meander belt.

The Loam and Sand Ridges.

The Lake-shore Loam Ridges.

Although all the Victorian streams in the area under consideration, except the Dunmunkle Creek, terminate in shallow lakes, the most complex lake system is that developed on the flood plains of the Loddon, Avoca, and Murray Rivers, between Boort, Kerang, and Swan Hill. Some of the lakes in this district are fed by the Murray anabranches, some by the Avoca, others by the Loddon. In some there is both an inlet and an outlet; others, again, have neither.

A feature of these lakes is that each possesses on its eastern side a loam ridge, crescentic in plan and with a smooth, even surface whose elevation decreases towards its northern and southern ends. There can be little doubt that the origin of these ridges is in some way bound up with the action of the westerly winds, which are dominant in causing sand drift in the Mallee. While the formation of littoral sand dunes around lake shores is readily understandable, especially in the case of lakes with sandy floors that are exposed during dry seasons, the crescentic loam ridges are not so susceptible of ready interpretation.

Sand or loam ridges occur on the eastern sides of practically every lake and swamp in far western and northern Victoria. Those of the Corop district have recently been described by Harris (1938), who refers to their occurrence around Lake Cooper and the nearby swamps. All the Mallee and Wimmera lakes, and most of the swamps, are supplied with one or more ridges on their eastern sides, and the Myarring Swamp in Co. Normanby has such a ridge. Furthermore, in the volcanic plains of the Western District, Lakes Colongulac and Kariah have "dunes" of black loam on their south-eastern sides. Normal littoral sand dunes occur on the eastern shores of Lake Hindmarsh.

The littoral sand dunes are clearly due to the action of westerly winds on the sands exposed on the lake floors during dry seasons. The form of the resulting dunes differs from that of typical dunes of sandy deserts and marine coasts chiefly in the rounding of the slopes, for sand-fall slopes in which the sand is at its angle of rest are not found around the lake shores.

In contrast with these sand dunes, however, the crescentic loam ridges have a very regular form (see Fig. 5B), and are composed practically entirely of extremely fine particles resembling true aeolian loess. Like the loess, also, they contain concretions of calcium carbonate. A mechanical analysis of loam from the ridge on the eastern side of Kangaroo Lake, kindly made for me by Mr. G. Baker, showed that the sand fraction (0.5 mm. and over) is only 6.4 per cent., the silt fraction 78.3 per cent., and the proportion of material soluble in hydrochloric acid 15.3 per cent. The regular form of the ridges indicates that it is highly improbable that they should have accumulated like dunes by the arrest of detritus moving under aeolian traction or saltation from the lake floors during dry periods. Such a process of drift of detritus typically results in hummocky sand accumulations, though the regularity of barchans is comparable with that of the loam ridges. Barchans, however, are mobile, and the loam ridges fixed in position. The chief question that arises concerning their origin is, did they form during times when the lakes were dry or when they were full? When the lakes are dry the lake floors would be a source of supply of fine dust which would undoubtedly be transported eastwards by the dominant westerly winds. The material of the lake floors, however, is so fine grained that much of it would undoubtedly be lifted into the air by strong winds, and it is unlikely that it would be re-deposited on the lake shores, for there is no particular feature there that would cause dust to be deposited.

On the other hand, when there is water in the lakes in summer, strong westerly, north-westerly, or south-westerly winds would often carry large supplies of dust from outside the area or from the Murray flood plain. These winds would

also whip up spray from the lakes, and this spray would capture dust from the air and carry it down in falling on the eastern shores of the lakes. Thus, in time a ridge would be built up. This hypothesis explains the smooth, regular contours of the ridges, the fact that they are composed of fine loam with a very small proportion of sand, and their restriction to the shores of lakes.

In regard to the necessity for the presence of water in the lakes in forming the ridges, an area in the Parish of Benjeroop is instructive (fig. 5A). There, two small lakes, now salt, occupy basins that were clearly formerly occupied by larger lakes, fed by Loddon anabranches. Loam ridges were formed on the eastern shores of these former lakes, but as the area of the lakes has shrunk, a process that appears to have gone on in two stages, smaller ridges were formed on the shores of the shrunken lake remnants. Each ridge follows the edge of the lake on whose shores it formed. Thus, it is clear that it is the presence of water which is the controlling factor in their formation, and not the existence of a dry lake bed. The salinity of the lake waters would also aid in the building of the ridges, for the salts deposited from the evaporation of spray droplets would be hygroscopic, and thus tend to retain dust blown along the surface of the ground. This hypothesis would explain the fact that the ridges around lakes that have been kept artificially full for years are still, in many instances, perfectly preserved, except for gullying due to over-grazing or trenching. Some lakes, e.g., Kangaroo Lake and Lake Charm, have a series of ridges on their shores. It appears that perhaps owing to tilting downwards to the west, or to siltation, these lakes have migrated westwards in the past, leaving a series of ridges behind.

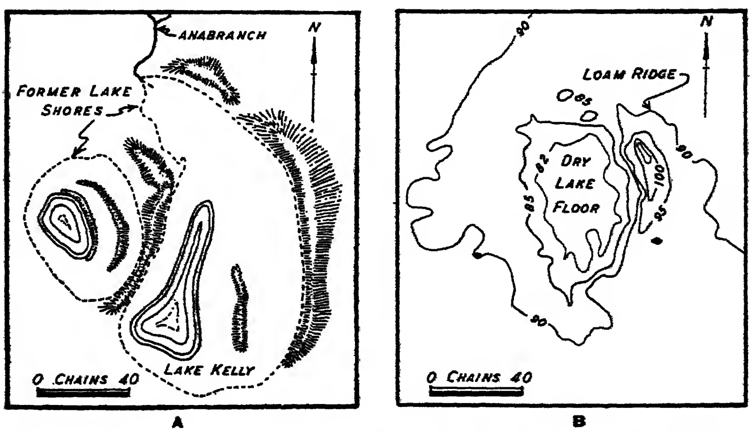

Fig. 5.—A. Map showing the relationship of loam ridges to lakes, Parish of Benjeroop. B. Contour map of a loam ridge and dry lake floor, Parish of Boort. Elevations in feet.

An interesting corollary of the above theory is that low loam ridges might be expected to occur along the eastern sides of the more permanent reaches of the streams in northern Victoria. Such loess-loam formations could be differentiated from natural levee banks by their restriction to the eastern sides of the streams. In the Parish of Benjeroop a well-marked meander of a Loddon anabranch possesses such a ridge, and I am informed by Mr. Rogerson, of the State Rivers and Water Supply Commission, that low loam mounds, used as kitchen middens by the aboriginals, occur along the Murray. As a result of subsequent changes in the stream channels, such loess-loam mounds would be left on the flood plain in an apparently haphazard way. Harris (1938) has described loam ridges, older than the present Murray course, in the Echuca district, and it may be that these were formed in the manner suggested above.

The Sand Ridges.

A characteristic of those parts of the Mallee that are elevated above the level of possible flooding by rivers, or by the water of lakes or swamps, is the presence of sand ridges similar in many respects to those described by Madigan (1936) in the desert areas of Central Australia. Over large areas the ridges are sub-parallel, with a general trend a little north of east and north of west, but in some of the "desert" areas they are irregular, and are referred to by surveyors as "jumbled." The average distance apart of the parallel ridges between Ouyen and Red Cliffs is about 16 chains, and the highest ridges in this district are 40 feet above the neighbouring troughs, though the average elevation is only about 20 feet. In areas such as the Little and Big "Deserts" and near Hattah, where the surface sand is loose and friable, sand drift occurs even in virgin scrub-covered country. In these areas the sand is not lifted far above the ground by strong winds, but there is a general superficial drift among the scrub.

In the Big Desert the southern slopes of the ridges are the steeper, and this is also true of the ridges between Ouyen and Hattah (see Fig. 6). Madigan has noted that the Central Australian ridges are asymmetrical, a feature he ascribes

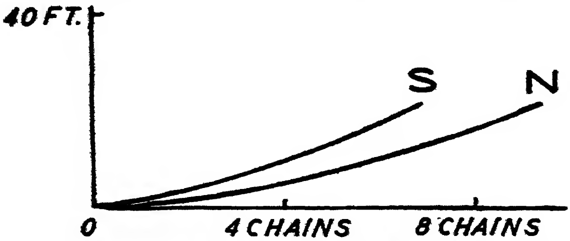

Fig. 6.—Comparison of the average slopes of northern (N) and southern (S) sides of sand ridges, north of Ouyen.

to the action of winds of secondary importance, coming from a quarter different from dominant winds that cause the ridges to develop. The persistence of these sand ridges for long distances, and their regular spacing (see fig. 7), are still unexplained. It is, however, a matter of common knowledge that the main direction of sand drift in the Mallee is from west to east, and there is no doubt that the sand ridges are longitudinal and not transverse to the drift-producing winds.

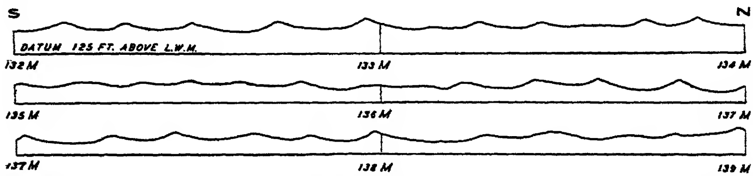

Fig. 7.—Cross-sections of sand ridges between Ouyen and Hattah. Horizontal scale. 1 inch = ¼ mile; vertical scale, 1 inch = 500 feet. For distances from Melbourne add 154 miles 63 chains to local mileages shown.

Evidence of the permanence of the ridges is afforded by their structure, as revealed in railway sections between Ouyen and Hattah. In a ridge at the 290-mile post on the Calder Highway, three hard calcareous "travertine" horizons occur with intervening sandy layers. The "travertine" bands are approximately parallel to the surface slopes of the ridge. In a ridge at 290¼ miles, two such travertine bands are visible (Pl. xxiv., fig. 2). Mineralogical analyses of the various hard and soft layers in this latter ridge have been kindly supplied to me by Mr. G. Baker, M.Sc. These show that quartz, which is the chief mineral component of all the layers, is accompanied also by andalusite, ilmenite, leucoxene, magnetite, rutile, sillimanite, tourmaline, and zircon. In the sandy layers A, B, C, and D (Pl. xxiv, fig. 2), biotite is also present, but this mineral is absent from the calcareous bands. Chlorite, which occurs in C, and hornblende, which is rare in A, C, and D, are also absent from the calcareous layers. The latter, too, contain very fine dust which is present at most in traces in the sands. It would appear that these fine particles have been washed from the sands and "fixed" in the calcareous layers, in which the calcareous cement has been chemically deposited between the sand grains, forcing them apart. There can be little doubt that the hard calcareous bands are soil horizons, the upper one being that now in process of formation. As no known pedological process is capable of developing superimposed calcareous horizons from an initial uniform rock mass, it appears to be reasonably certain that the lower horizons are buried soils. This indicates that the ridges have been situated in their present positions over a long period, and, furthermore, that they have grown in size intermittently by the addition of further supplies of sand, the process taking place in three stages. It is most probable that these three stages

of growth are to be correlated with periods of aridity which alternated with moister periods, when the soil horizons were formed and the movement of sand was inhibited by vegetation or by closing down of the source of supply. The immediate past was, if the above interpretation be correct, a period of relatively high rainfall. Evidence from other parts of Victoria to some extent supports this. Thus, between Mordialloc and Brighton, fixed sand ridges occur, which are not beach ridges formed during the uplift of the coastal plain, but are directly due to former aeolian sand drift, which has now ceased.

Abbott's studies of the copi deposits in the northern Mallee also indicate that there have been climatic changes during the recent past. Sections of the copi hills, which rise above the level ccpi plains near Cowangi, show that pure powdery copi typically overlies impure sandy copi (see fig. 8). It is probable

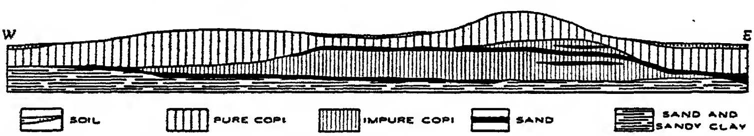

Fig. 8.—Cross-section of copi deposits, east of Cowangie; Allotment 7, Parish of Tutye. Vertical scale, 1 inch = 45 feet; horizontal scale, 1 inch = 150 feet. After S. B. Abbot.

that these copi hills are the weathered remains of gypsum dunes such as have been described in South Australia by Jack (1930). The impure copi, which invariably contains sand lenticles, is composed of granular "seed" gypsum, often showing aeolian cross bedding. If, as Jack suggests, the powdery copi at the surface is formed by the weathering of the "seed" gypsum, then it is likely that the climatic or drainage conditions in the northern Mallee have changed since the impure copi was laid down and subsequently blown up into gypsum dunes, for this process is not now operative in the copi districts of Co. Weeah. It is probable that the present and the immediate past, during which sand drift has been arrested in many places (except where the conditions have been changed by the activities of man), and solution and re-deposition of the dunes of "seed" gypsum has developed powdery copi at the surface, were wetter than earlier periods.

Relation of Sand Ridges to Streams.

Below Lake Albacutya, the Outlet Creek makes its way between a well-developed series of east-west sand ridges. For long periods the Outlet Creek is dry, but it is said to carry water on an average about once every twenty years. The pattern of the drainage of the creek through the ridges is remarkable. Effluents run off to the east and west, feeding basins among the ridges, which become ephemeral lakes such as Lake Brambruck. These lakes are analagous to, though much smaller than, the

bajirs described by Sven Hedin, which are formed by the flooding of the Tarim, in Central Asia, among the sand ridges that cross its course.

The development of a drainage line through the ridges in this fashion indicates two things: firstly, the drift of sand is not sufficiently rapid to effectively block the stream course during its dry periods, and secondly, the ridges probably developed before the stream began to cross them; otherwise they would not have developed on the eastern side of the stream, if the supply of sand is from the west. Thus, again, the evidence indicates that at the present time the sand drift is not so active as it once was, and that the present is a time of relatively high rainfall.

PHYSIOGRAPHIC DIVISIONS OF THE NORTH-WESTERN PLAINS.

The Murray Valley.

The three major physiographic divisions of the area are the Murray Valley, the Mallee, and the Wimmera. The Murray Valley is the flood plain of the Murray, which is subject to periodical inundations except where artificial levee banks have been constructed. As shown by Tate (1895), Patton (1930), and Zimmer (1937), this region carries a characteristic association of Red Gum and Grey Box, both of which require flooding by river waters for their growth. Insufficient is known of the physiographic history of the Murray in Victoria to elucidate the details of the Murray Valley. It is notable, however, that the river is deflected northwards when it meets the Cannie Ridge at Swan Hill, and that it is encroaching on the fixed sand ridges near Wood Wood and elsewhere. It keeps close to the northern end of the Tyrrell Ridge at Robinvale, but is deflected northwards again at the Hattah Lakes, where it is evident that marked drainage modifications have occurred, and flows close to the eastern edge of the Red Cliffs Ridge to Mildura. It is only near the Hattah Lakes, however, that there is any indication of recent changes in the Murray's course, such as may have resulted from tectonic movements. In the other cases the ridges appear to be older than the river, which is encroaching on them.

The Mallee.

The Victorian Mallee is, in general, an areic region (Fenner, 1931). Over practically the whole area aeolian sand ridges occur. The major topographic features are ridges and troughs with a trend varying from north-south to north-west–south-east, and also broad basins. Floristically, it is characterized in part by an association consisting chiefly of stunted eucalyptus (Mallee scrub), together with Murray Pine and Belah which typically grow on the ridges (see Patton, 1930, and Kenyon, 1914-15).

In the south and east this association is replaced by the grasslands and Savannah woodlands of the Wimmera and the Northern District Plains.

Wood (1929) has stated that the southern boundary of the Mallee floral association follows the line of 20-in. winter rainfall (May–October). On his map he shows a 20-in. isohyet, which is actually the average annual figure and not that for May-October. Data recently published by the Commonwealth Bureau of Meteorology (Watt, 1937) show that the 20-in. average annual isohyet corresponds approximately to the 12-in. isohyet for May–October, but, in any case, this line is too far south to be acceptable as the southern boundary of the Mallee. Patton (1929) has already shown that it is the 15-in. annual average isohyet which forms the approximate southern boundary of the Mallee in Victoria. Many factors other than rainfall are, however, involved, and the combined effects of these is reflected in the vegetation, which may therefore be used to define the boundary for physiographic purposes.

On the topographic map (fig. 1) the boundary of Mallee land, as determined from an examination of the plant communities, is shown. This boundary was surveyed many years ago, and is shown on the standard base map of the Lands Department, on a scale of 8 miles to 1 inch. The boundary reveals an interesting relationship to topography. Along the river valleys, for instance, tongues of the Wimmera type of country, or of Redgum and Box associations, extend northwards into the Mallee. On the other hand, on the ridges the Mallee boundary swings southwards into regions of presumably higher rainfall than the main Mallee area. In Co. Lowan the ridges are composed of sandstone which does not appear in the valleys, where soils of the Wimmera type occur. These sandstone ridges yield an extremely loose sandy soil, which clearly is the determining factor in vegetation control. The Little "Desert," which is often classed as Mallee, actually carries *Banksia, Casuarina, Acacia, Leptospermum,* and *Xanthorrhea,* but not typical Mallee scrub eucalypts (d'Alton, 1913). This association is somewhat similar to that found on areas of Tertiary sands in other parts of the State, e.g., on the flanks of the Otway Ranges.

It would appear that the chief factors involved in the distinction between the Mallee and the country south and east of it are precipitation, evaporation, rock type, porosity of the superficial deposits, drainage away from high areas, and supply of water from streams that rise in regions of higher rainfall.

The Wimmera.

For physiographic purposes, I propose to term the region south of the Mallee and north of the Western Highlands the "Wimmera." This region is characterized by extensive flood

plain deposits of river alluvium, both Recent and older; by flowing streams, many of which are aggrading and have anastamosing courses or give off anabranches, and by an average annual rainfall between 15 and 22 inches. As remarked in the introduction, it is convenient to regard the Loddon River as the eastern boundary of the Wimmera. Both the Wimmera and the Mallee exhibit well-defined topographic ridges, troughs, and basins, but such features are not found further east in the Northern District Plains, except where bedrock outcrops. Also, the Loddon joins the Murray, whereas the streams of the Wimmera do not. In Co. Lowan the boundary of the Wimmera may be taken as the northern limit of dissection by tributaries to the Glenelg, and by the Mosquito Creek and neighbouring streams, that flow into South Australia.

Summary and Conclusions.

The history of the ancient Murray Gulf may be summarized as follows:—

1. Sagging in post-Cretaceous times was accompanied by the deposition of a series of continental, estuarine, and marine ligneous clays, lignites, sands, and gravels, mainly Oligocene in age.

2. This sagging was accompanied by a general rise of sea level in southern Australia during Miocene and Lower Pliocene times, during which marine limestones (chiefly) were deposited.

3. By Werrikooian (Upper Pliocene) times the sea coast had retreated to the south-eastern portions of the Gulf, continental and estuarine conditions prevailing in the north-east and north.

4. Positive movements of elevation during Pleistocene and Recent times were accompanied by faulting and warping. The sea coast retreated to its present position, leaving behind the old beach ridges and littoral sands that extend from Narracoorte to the coast in South Australia and south-western Victoria.

5. On the Pleistocene land surface, streams fed by a plentiful rainfall deposited a veneer of sands and silts over the older beds. The Murray may in early Pleistocene times have entered the sea near Tintinarra, its course being through the Murrayville district (see Howchin, 1929).

6. The Pleistocene and Recent earth movements above mentioned caused extensive changes in the course of the Murray, as outlined in the text. Lakes were formed upstream from the Pyap Bend and Overland Corner, and in these lakes, or their shrunken remnants, copi and ostracodal limestones were deposited.

7. The rainfall decreased after the Pleistocene, but during Recent times there have been relatively wetter and drier periods, the present and immediate past being relatively wet.

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Fig. 1.

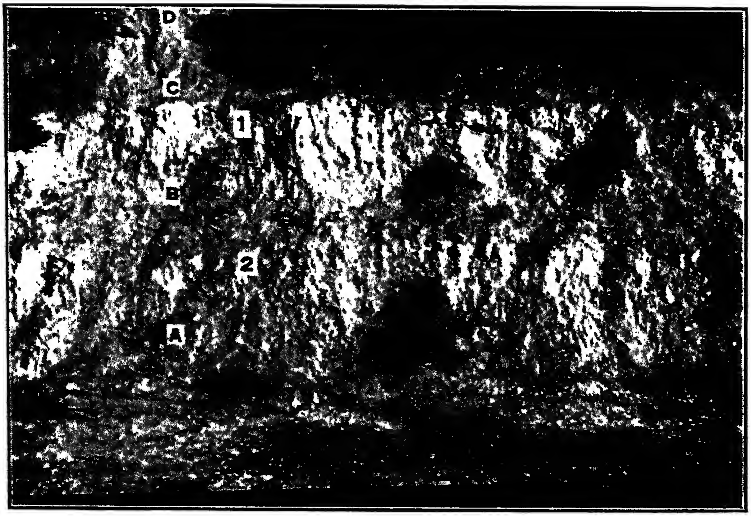

Fig. 2.

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Explanation of Plate XXIV.

Fig. 1.—The dissected plain in County Dundas, north of Coleraine.

Fig. 2.—Section across a sand ridge, north of Ouyen. A, B, C, sandy layers; D, superficial, loose sand; 1, upper calcareous layer; 2, lower calcareous layer.

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Rivett, Sir David, M.A., D.Sc., Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2 1911
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Caldwell, J. J., Geological Survey Office, Bendigo, Vic. 1930
Cox, H. M. S., Wombat Park, Daylesford 1931
Crawford, W., Gisborne, Vic. 1920
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Associates.

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Bage, Miss F., M.Sc., Women's College, Kangaroo Point, Brisbane, Qld. 1906
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Blake, A. S., 19 Rose-street, Ivanhoe, N.21 1929
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Heysen, Mrs. D., P.O. Box 10, Kalangadoo, South Australia .. 1935
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Jack, A. K., M.Sc., 49 Aroona-road, Caulfield, S.E.7 1913
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Lennox, Mrs. Gordon, M.Sc., c/o C.S.I.R., Box 109, Canberra City, Canberra, F.C.T. 1934
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PART II.

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Art. I.—*The Measurement of Soil Structure.*

By R. G. DOWNES, B.Agr.Sc., and G. W. LEEPER, M.Sc.

[Read 9th March, 1939; issued separately, 1st March, 1940.]

Introduction.

It has long been recognized that soil in its natural state is different from the ground-up material which is analysed in the laboratory for its physical and chemical properties. The particles of sand, silt, clay, and organic matter into which this material may be separated are arranged in nature to form composite units, or aggregates. It is this arrangement which is called the "structure" of the soil. The mechanism by which the aggregates are formed presents a complex fundamental problem on which Russell's work (1934, 1938 i) is outstanding. We are not concerned here with this fundamental problem but rather with its practical outcome and with an attempt to find methods of measuring structure in the laboratory.

A soil of good structure contains a large percentage of aggregates of the order of ½–1 mm. diameter or a little larger, and these aggregates are stable towards rain. Such a soil allows excess water to drain away rapidly, since the spaces between the aggregates are as large as those between grains of coarse sand. Surface run-off is therefore low, and the risk of erosion is accordingly small. Further, a good structured soil can be easily worked over a wide range of moisture content. A soil of poor structure, on the other hand, contains a big proportion of its fine fractions as individual particles. If there is more than a small amount of dispersed clay present, such soil is sticky when wet, and forms large, hard clods when dry. Such a soil is badly aerated during wet spells, since the spaces between the individual particles are small. It can be worked successfully only between narrow limits of moisture.

Poor-structured soils include not only those which easily become sticky because of their high content of dispersed clay, but also those which are liable to "pack" or set hard after heavy rain. Soils which pack are typically high in silt and fine sand, and low in clay. Their capacity for aggregation is therefore low, especially if organic matter is deficient. They are particularly dense, and since they possess few large pores they may be badly aerated in wet weather in spite of good underdrainage. When cultivated they become powdery, and are liable to erosion by both wind and water. Both roots and shoots may find difficulty in penetrating such hard soils, in contrast to the ease with which plants penetrate through good-structured soil.

It is clear from the foregoing discussion that the structure of soil is of great agricultural importance. There is an urgent need for the development of satisfactory methods of expressing structure in numerical terms, especially if we are to measure and compare the changes that take place under different systems of cultivation or cropping. Since about 1930 the measurement of structure has begun to receive the attention it deserves. Unfortunately a great deal of the most interesting work is available only in Russian; but Hénin (1938) and E. W. Russell (1938 ii) have recently prepared valuable summaries of the experimental methods that have been proposed. The technique of such work must always include some arbitrary rules, and it is to be hoped that workers in different countries will soon reach agreement as to some of these. Meanwhile, we have attempted to arrive at a standard procedure for the study of Australian soils, bearing in mind two important principles: firstly, that the laboratory measurements should give a good correlation with observations in the field; secondly, that the methods should be simple and rapid.

The samples for study were chosen as follows: Firstly, representative soils were taken from well known types with a good or bad agricultural reputation. Secondly, a few types were studied in detail in order to test the effect of differences in management or cropping.

Description of the Soils Studied.

Kerikeri Clay Loam.

A highly ferruginous soil from North Auckland, New Zealand. It is derived from basalt, is high in clay, and has an extremely good structure.

Penola (S.A.).

A black reclaimed swamp soil, neutral in reaction, high in clay and in organic matter and having a very good structure. Water applied to the surface soaks through with remarkable speed.

Berwick (25 miles east of Melbourne).

(i) *Black Clay on Oligocene Basalt.*—Of excellent structure, very permeable, rich in organic matter, and non-erosive, although low in exchangeable calcium.

(ii) *Hallam Loam.*—Typical of the podzols found in southern Victoria on the colluvium from hills of Silurian mudstone. Very poor structure, silty, low in humus and colloids and tends to "pack."

Trentham, Victoria.

Red loam—rather typical of the soils developed on basalt in the wetter parts of Victoria. A deep friable soil high in clay and having a good structure. This red loam and the black clay from Berwick are probably analogous to the red and black types formed on basalt in Tasmania as described by Stephens (1937).

Werribee (South Central Victoria).

Samples were collected from the State Research Farm, where breeding and manurial experiments on cereals are carried out. The soils are derived from Pleistocene basalt.

(1) The "red" soil, denoted as "Werribee R," is a red-brown clay loam of pH 6, overlying red clay. This surface soil has a poor structure, and is difficult to work. In some winters the water lies on the surface for several days. This soil type is said to have deteriorated in structure since it was first cultivated about 50 years ago. Applications of gypsum at the rate of 1½ to 2 tons per acre cause striking improvements in wet seasons. For example, during the late autumn and winter of 1935 the land remained wet following a total fall of 5 inches of rain in April. Gypsum at the rate of 2 tons per acre applied to experimental oat plots so improved the aeration during the early growth of the plants that the treated plots yielded 51.6 cwt. of hay per acre, as compared to 37.6 cwt. for the untreated. Samples of this red soil were taken both from cultivated paddocks and from land that had been left under native grasses. A rather better type than the prevalent "red" soil was studied in certain green manurial trials which are also discussed later.

(2) The "black" soil, denoted as "Werribee B," occurs in patches up to 20 yards across in paddocks of predominantly red soil. This is a dark grey calcareous clay, of excellent structure. It does not get waterlogged, and is far more fertile than the red type, as may be seen in the spring from the far denser growth of cereals on the black soil.

WIMMERA (Victoria).

The soils are derived from unconsolidated quaternary sediments. Most of the samples were collected near Horsham.

(1) The "red" soil is a red-brown loam overlying red clay, with calcareous clay at a lower level. This type has a rather poor structure, and is inferior generally to the "black" soil, with which it alternates through the district. The sample used in this work, Wimmera R, was collected at Longerenong Agricultural College.

(2) The "black" soil of the Wimmera has become famous for its prolific crops of wheat. This type is a grey calcareous clay. In the natural state it occurs in the formation locally known as "crabholey," in which puffs or hummocks of calcareous self-mulching clay alternate with depressions which are non-calcareous and less clayey. When the land is levelled and cultivated the good structure of the puffs is extended over the whole formation. These soils were studied from three points of view: firstly, the comparison of virgin land with cultivated land; secondly, the comparison of different systems of cultivation of fallows; and thirdly, the association of structure with windblowing. This type is denoted as "Wimmera B," and the puffs and depressions in the crabhole complex as "Wimmera BP" and "Wimmera BD" respectively.

MERRIGUM, GOULBURN VALLEY (Northern Victoria).

This soil is a red-brown loam to sandy loam, neutral in reaction, lying over a clay subsoil, and derived from quaternary sediments. The district includes irrigated orchards and dry land that has formerly been heavily cropped with wheat. It is believed that the structure, which is poor, has deteriorated under cultivation.

RUTHERGLEN (North-eastern Victoria).

The soil of the State Farm at Rutherglen is a greyish-brown non-calcareous sandy loam containing ironstone gravel. The profile is intermediate between the red-brown earths of the Goulburn Valley and the podzolic soils in the wetter country to the south and east. The structure of this soil is very poor. It packs very easily, and its poor aeration during wet spells seriously limits the growth of wheat crops. The soil is particularly variable. The chief interest with this type is the possibility of improvement with vigorous pasture or with green manure.

DOOKIE (Northern Victoria).

A red, good-structured soil derived from metamorphic rocks occurs on a hillside, and a grey calcareous soil similar to the "black" soil of the Wimmera occurs in flat areas which were formerly swampy.

At Werribee, Dookie, and Merrigum, and in the Wimmera, the climate is on the dry side, and when wheat is grown the land is prepared by a year of bare fallow.

Measurement of Structure.

The methods of measuring structure may be classified into two groups, direct and indirect. The direct methods consist simply of separating the soil into fractions of different sizes on a set of sieves. This may be done in air or under water. From these analyses the respective percentages are obtained, either of the actual aggregates or of the water-stable aggregates of various sizes present in the soil at the time of sampling. We shall ignore the former figure, since it represents only a temporary phase of structure which might be completely changed within 24 hours. The indirect methods consist of the measurement of specific physical properties which are thought to be correlated with soil structure. Pore space of the soil *in situ* is probably the most important of these properties.

Measurement of Water-Stable Aggregates.

It must first be decided what is the smallest aggregate that should be included in an analysis. Many Russian writers measure the material of diameter greater than 0.25mm., while others such as Baver and Rhoades (1932) prefer to include aggregates down to 0.05 mm. or less. These limits correspond roughly to what some workers have described as "macro-structure" and "micro-structure" respectively, and there is as yet no agreement as to their relative importance. Each is dealt with here in turn.

(A) MACRO-STRUCTURE. (Aggregates greater than 0.25 mm.)

The first method for measuring the water-stable aggregates in a soil is associated with Tiulin (1928). It consists simply of washing the soil on a set of sieves by moving them up and down in a bucket of water at a constant rate. Meyer and Rennenkampff's (1936) apparatus consists of a cylinder 40 cm. high in which is placed a set of sieves 9 cm. in diameter and ranging in mesh from 4 mm. to $\frac{1}{4}$ mm. holes. The cylinder is filled with tap-water from below, until the level of the 4 mm. sieve, on which the soil initially rests, is just exceeded. At this point the cylinder is emptied by a siphon, and the filling and emptying continue automatically. In the apparatus as published the sieves are fitted with rubber flanges which touch the walls of the cylinder. These flanges are troublesome to fit and work with and we have not used them in our work.

This apparatus seemed the most promising, and we have accordingly tried to standardize the technique. This has involved certain problems which can be discussed under the following headings:—

(i) Sampling in the field.
(ii) Sub-sampling.
(iii) Pretreatment methods.
(iv) Time and manner of washing.
(v) Expression of results.
(vi) Lower limit of sieves.

(i) *Sampling in the Field.*—This must involve the least possible damage to the natural structure. For this reason we used a sampling tool essentially similar in design to that proposed by Coile (1936). This removes a core 8.5 cm. deep and 442 c.c. in volume, without compaction or other interference, and this sample can also be used to determine the apparent specific gravity and the pore space.

(ii) *Sub-sampling.*—Because of the size of sieves (9 cm. diameter) the maximum sample allowable for any one test is 25 gm. If more is used, there is a risk that the finer aggregates may be retained through the filtering effect of the soil on each sieve. Because of this limitation and the nature of the material collected from the field it is difficult to get a true representative sub-sample. An attempt to improve on the ordinary sub-sampling method was made by using the composite sampling method quoted by Tsyganov (1935). The bulk sample was first separated into four fractions of the following sizes:—greater than 4 mm., 4–1 mm., 1–$\frac{1}{4}$ mm., and less than $\frac{1}{4}$ mm. From these fractions a sub-sample was constructed so that each of them was present in the same proportions as in the bulk sample. It was found on comparison of duplicate results obtained from both sampling methods that there was little difference in variability and we decided that the considerable work involved in the new sampling technique was not warranted. Russell, however (1938 ii) considers that this additional work is worth while.

At this point the problem arises of whether analysis should be done on the field-moist or air-dry material. Since structure is markedly influenced by wetting and drying it is essential to standardize this matter. Selected soils were therefore analysed in the Meyer apparatus before and after drying in the laboratory, and some of the results are given in Table I. It will be seen that the dried samples have a more stable structure than the fresh soils and also give more erratic results, as is shown by their higher co-efficient of variation. It seems better therefore to analyse the soil in the moist condition, on account of the higher reproducibility as well as the greater approximation to natural conditions.

TABLE I.—COMPARISON OF RESULTS FROM FIELD MOIST AND AIR DRY MATERIAL.

Figures represent the mean percentages of each fraction. Air dry figures are means of quadruplicates while the Field Moist are means of duplicates.

Soil Type.	Treatment.	Mean Percentages of Fractions.				Standard dev. of material < ½ mm.
		> 4 mm.	4–1 mm.	1–½ mm.	< ½ mm.	
Werribee R ..	Field moist ..	0·2	6·3	16·8	76·9	4·8
	Air dry	12·4	17·7	31·3	38·8	9·1
Wimmera B ..	Field moist ..	0·4	0·7	42·5	56·5	3·4
	Air dry	0·6	5·6	52·6	40·7	7·7
Merrigum	Field moist ..	0·4	1·8	6·5	90·9	0·1
	Air dry	1·3	7·4	26·1	64·1	7·9

(iii) *Pretreatment of Sample.*—The soil may be either placed directly on the sieves or first brought to capillary saturation by moistening from below. Sokolovsky (1933) in a valuable practical review of the whole subject quotes figures to show the stabilizing influence of this capillary moistening. Our own figures confirm his findings (see Table II). We have adopted this method as a routine since it tends to give more nearly equal results for the same soil sampled at different moisture contents.

TABLE II.—COMPARISON OF ANALYSIS ON SOILS WITH AND WITHOUT PREVIOUS CAPILLARY SATURATION.

Soil Type.	Treatment.	Mean Percentages of Fractions.			
		> 4 mm.	4–1 mm.	1–½ mm.	< ½ mm.
Trentham Red Loam	Capillary soaked ..	12·0	28·0	36·4	25·8
	Flooded	10·5	14·9	39·2	35·2
Penola	Capillary soaked ..	5·3	53·8	29·0	11·8
	Flooded	2·8	43·6	28·4	17·6
Werribee R.2 ..	Capillary soaked ..	0·5	4·2	25·2	72·7
	Flooded	0·1	3·1	17·5	79·0
Wimmera B.12 ..	Capillary soaked ..	..	4·1	56·9	38·9
	Flooded	..	0·4	26·5	73·1

Another problem concerns the pretreatment of certain soil types such as the Werribee R and Wimmera BD, which become soft and plastic and remain on the 4 mm. sieve although there are obviously no true aggregates of that size in such soils. These soils were shaken with water for various times before being analysed in the Meyer apparatus. When this was done these lumps disintegrated giving a large increase of material less than

$\frac{1}{4}$ mm. diameter. If soils of good structure are subjected to the same treatment there is no appreciable increase of material less than $\frac{1}{4}$ mm. size but only an increase in the intermediate aggregates at the expense of the larger ones (see Table III).

TABLE III.—COMPARISON OF THE EFFECT OF VARIOUS TIMES OF SHAKING DIFFERENT SOIL TYPES.

Soil.	Treatment.	> 4 mm.	4–1 mm.	1–$\frac{1}{4}$ mm.	< $\frac{1}{4}$ mm.	Percentage disaggregation.
Kerikeri (N.Z.) Clay	Not shaken ..	30·8	47·3	13·8	8·0	8·3
	30 minutes shaken	12·6	62·1	17·6	7·9	8·2
Hallam loam ..	Not shaken ..	74·6	10·8	4·9	9·5	10·5
	5 minutes shaken	51·8	15·4	7·2	25·4	28·2
	30 minutes shaken	10·2	15·4	8·2	65·4	73·0
Penola	Not shaken ..	9·0	41·5	26·5	22·4	22·9
	30 minutes shaken	1·0	44·8	27·8	25·2	25·7
Wimmera B (puff) Grassland	Not shaken ..	14·5	37·1	24·2	23·3	25·4
	5 minutes shaken	1·5	31·4	37·2	30·0	32·7
	30 minutes shaken	0·9	31·4	35·2	32·4	35·3
Wimmera B (depression) Grassland	Not shaken ..	27·2	22·6	19·1	31·0	37·3
	5 minutes shaken	6·4	14·3	29·8	49·5	59·5
	30 minutes shaken	0·7	6·6	31·1	61·5	74·0
Merrigum (pasture)	Not shaken ..	57·5	8·8	2·3	31·4	32·0
	5 minutes shaken	16·8	18·6	14·2	50·6	51·4
	30 minutes shaken	8·8	15·8	13·9	61·6	62·5

(iv) *Time and Manner of Washing.*—The soil is washed on the sieves until the outflowing water is completely clear. This usually takes about 20 minutes but may take longer for some soils. Extra washing beyond this stage has no effect on the result. Neither does the long washing appear to disperse the soil more than when done by Tiulin's method. In fact, in spite of the purity of tapwater in Melbourne, those differences that do occur are in the opposite direction to that expected, probably because of the more vigorous swirl of the water in Tiulin's method.

After washing is completed the sieves are separated and dried in an oven at 105°C. and the material from each sieve is weighed after coming to equilibrium with atmospheric humidity. By means of an air-damped rapid balance these weighings can be accomplished in a short time.

After weighing, the material is retained for estimating the amount of coarse sand greater than $\frac{1}{4}$ mm. diameter which must be allowed for in calculating the degree of aggregation of the soil.

(v) *Expression of Results.*—We found that the percentage of "dust"—that is, material less than $\frac{1}{4}$ mm.—was a satisfactory figure by which these results could be expressed. For soils having large amounts of coarse sand the "dust" figures require adjusting as may be shown by the figures in Table IV. From this table it may be seen that the percentage of "dust" calculated in the normal way gives a false impression, making the soil appear better than it is in actual fact. It is preferable to think in terms of the percentage of material less than $\frac{1}{4}$ mm. in the soil which is shown in the Meyer apparatus to be aggregated. The best expression for such a soil is probably the percentage "disaggregation" which is "dust" $\times \dfrac{100}{100 - \text{coarse sand.}}$

TABLE IV.—TYPICAL FIGURES FOR A RUTHERGLEN SOIL.

Weight of Soil.	Weight of C. Sand.	Weight of material < $\frac{1}{4}$ mm. in Soil.	Total weight of aggregates > $\frac{1}{4}$ mm.	Meyer fraction < $\frac{1}{4}$ mm.	Percentage "dust".	Percentage disaggregation.
22·24	3·86	18·38	6·18	16·06	72·2	87·4
20·94	4·71	16·23	6·51	14·43	68·9	88·9

(vi) *Lower Limit of Sieves.*—Attempts to include a $\frac{1}{8}$ mm. sieve in the set were unsuccessful owing to the fact that a sieve of that mesh creates considerable resistance to the passage of water which in turn causes serious variability of results.

Summarized Procedure for Meyer Analysis.

(*a*) Samples are taken from the field by the constant-volume sampler.

(*b*) After other tests, to be described later, have been made on the sample it can be sub-sampled in the ordinary manner, the sub-samples being of the order of 20–25 gm.

(*c*) Sub-samples are placed on a filter paper resting in a petri dish of water and allowed to soak in this capillary fashion.

(*d*) Sub-samples are introduced into the Meyer apparatus and there allowed to wash until the outflowing water is clear.

(*e*) Sieves are removed, separated and dried in the oven at 105°C.

(*f*) Material from each sieve is weighed separately after standing in air. This material is retained and dispersed.

(*g*) All material from sieves is decanted for sand. This sand is passed through sieve of $\frac{1}{4}$ mm. mesh and the coarse sand weighed.

(*h*) Percentage of "disaggregation" is calculated.

(B) MICRO-STRUCTURE.

Sieves cannot be used for determining aggregates below ¼ mm. diameter (see p. 8) and one must therefore rely on Stokes's Law connecting the size of a small particle with its rate of fall through a liquid. Bouyoucos (1935) has used a sensitive hydrometer to give a quick method of measuring the material remaining in suspension after a given time. Cole and Edlefsen (1935) designed a special sedimentation tube in an endeavour to obtain similar results gravimetrically, but we have found that their method is cumbersome and has no advantage over Bouyoucos's method.

Bouyoucos's hydrometer was designed originally for use in mechanical analysis of soil but it has not been widely adopted for this purpose, possibly because his tables for the relation between time of settling, hydrometer reading and particle size do not agree with Stokes' Law. Wintermyer et al. (1931) of the U.S. Bureau of Public Roads, have given this matter some consideration and have made several corrections which can be applied to the hydrometer reading. This has greatly increased the usefulness of the hydrometer.

We have used the hydrometer for measuring the microstructure in nineteen soils. A sample of 50 gm. of each soil was moistened in capillary fashion and placed in a tall cylinder with a litre of water. The soils were first mixed by gently inverting the cylinders six times by hand and the resistance to mechanical disturbance was further tested by taking hydrometer readings after end-over-end mechanical shakings for intervals of 5, 15, 30 and 60 minutes. In every case hydrometer readings were taken after standing for about half a minute and for two minutes.

Sizes corresponding to these approximate intervals are .07 mm. and .035 mm. diameter respectively. Assuming the specific gravity of the aggregates to be 1.93, the exact times of settling required for the measurement of these sizes can be calculated using the Bureau of Public Roads corrections. (The above figure of 1.93 is calculated from the value of 1.50 for the apparent density of an aggregate in air. Naturally it is not a universal figure.)

Analyses of the soils for percentages of sand greater than these two sizes were also made and the percentage disaggregation of the soils calculated for each treatment. From the collection of results in Table V it appears that the best indication of the relative structural merits of the soils is shown by the figure for 0.07 mm. particles after 15 minutes shaking. The size .07 mm. rather than .035 mm. diameter is chosen because it is considered that .035 mm. particles are much too small to be of use in forming a good structure. Fifteen minutes shaking seems to be the optimum amount of treatment necessary to show differences

between good soils such as Wimmera BP1 and bad soils such as Werribee R. Any longer time seems to be equally drastic to all types.

TABLE V.—SHOWING PERCENTAGE DISAGGREGATION OF MATERIAL < 0.07 MM. AND 0.035MM. DIAMETER RESPECTIVELY AS MEASURED BY THE SOIL HYDROMETER AFTER VARIOUS TIMES OF SHAKING.

Soil.	Percentage disaggregation of material < 0·07 mm. diameter.				Percentage disaggregation of material < 0·035 mm. diameter.			
	No shaking	5 min.	15 min.	30 min.	No shaking.	5 min.	15 min.	30 min.
Wimmera BP1—native grassland	6	18	27	39	5	14	22	33
Wimmera BD3—native grassland	21	41	52	68	16	38	47	67
Trentham red loam—under forest	5	14	22	31	3	10	17	25
Penola black clay	2	8	16	22	3	8	13	20
Werribee R1—native grassland	7	28	43	58	7	28	43	55
Werribee R3—cultivated 30 years	18	45	60	66	16	40	58	63

The procedure for measurement of structure with the hydrometer may be summarized thus:—

(*a*) A sub-sample of 50 gm. is moistened in a capillary fashion and placed in a cylinder.

(*b*) The cylinder is then filled up with water to the litre mark.

(*c*) It is shaken end-over-end mechanically for 15 minutes.

(*d*) It is shaken by hand two or three times to mix before putting aside to settle.

(*e*) The hydrometer is read after ½ minute settling, this time being corrected for temperature according to Wintermyer's tables.

(*f*) The percentage of sand greater than .07 mm. diameter is estimated by settling and decantation.

(*g*) The percentage of disaggregation is calculated.

The rapidity of this test is a strong point in its favour.

Apparent Specific Gravity and Pore Space as Indications of Structure.

The total pore-space may be divided into two classes, capillary and non-capillary. Capillary pore-space is that within the aggregates themselves and is a measure of the water-holding capacity of the soil. Non-capillary pore-space is that which exists between the aggregates and this indicates the degree of aeration and drainage of the soil. A soil in which both these figures are high combines the drought-resistance of clay with

the good aeration of coarse sand. Non-capillary pore-space is the more important in our investigations; it must necessarily be high in a well-aggregated soil in which the aggregates have the dimensions of coarse sand.

The apparent specific gravity of soil in the field may be used for calculating the total pore-space. Capillary pore-space depends on texture and so remains nearly constant for any one soil type; thus on the one soil, changes of apparent specific gravity represent changes of non-capillary pore space. Naturally one could not expect differences in apparent specific gravity to be correlated with differences between one soil type and another.

We have recorded the apparent specific gravity as simply the weight of the amount of oven-dry soil present in the field sample, divided by its volume (442 c.c.). The total pore-space may be calculated from this if the true specific gravity of the soil material is known. For most soils, it may be estimated approximately assuming a specific gravity of 2.65. The correct measurement of capillary pore-space is particularly difficult, and the problems involved have been fully discussed by Russell (1938 ii).

Apparent specific gravity is a valuable figure, easily and quickly measured, the figures for any one treatment of a particular soil type having a co-efficient of variation of approximately 3–5 per cent.

Crumb Strength as an Indication of Structure.

Several workers have measured crumb strength and have considered it as an indication of the structure of soil. Nikiforoff (1938) suggests that ideal structure combines low cohesion between aggregates with high cohesion within individual aggregates, from which it follows that structure may be estimated from the crushing strength of crumbs. According to Russell's (1934) theory of the nature of crumbs, sandy crumbs should be softer than those consisting almost entirely of clay.

Various pieces of apparatus have been used for measuring this crushing strength. The principle of the apparatus that we have designed is as follows:—A weight which just extends a spring balance to its maximum reading is gradually lowered on to the upper of two long strips of wooden board hinged at one end. The aggregate (2–3 mm. in diameter) is placed between the boards at the end distant from the hinge. On each board is a metal contact, that on the lower one being a flat strip of brass and that on the upper one an adjustable screw. These contacts are situated at the crushing end of the boards quite close to the point where the aggregate is placed.

Since measurements are only to be comparative and not absolute an arbitrary standard of crushing through a distance equal to half the diameter of the aggregate was adopted. The upper contact can be adjusted to suit this condition so that it makes contact when the aggregate has been crushed through

1–1½ mm. The two contacts are connected to an electric circuit in which there is a "buzzer." The force required for such crushing is determined by subtracting the actual reading at the sound of the "buzzer" from the maximum reading on the scale. To facilitate the procedure the scale and weight are lowered by a small windlass.

It was thought that crushing strength would be influenced by the relative humidity with which the soil is in equilibrium but exhaustive tests have shown that there are no significant differences within the range from 35 per cent. to 98 per cent. In some cases slight increases were noticed at 10 per cent. From the series of results given in Table VI it may be seen that there is no correlation between the crushing strength of aggregates and the structure of the soil. It is unreasonable to expect any correlation, since the factors contributing toward crumb strength are so complicated.

TABLE VI.—SHOWING PERCENTAGE DISAGGREGATION OF PARTICLES < 0.25MM. DIAMETER AND CRUSHING STRENGTH OF UNWASHED AGGREGATES (2–3 MM. DIAMETER) OF 4 SOILS.

—	Percentage disaggregation.	Crushing Strength.	
	Mean of 4 samples.	Mean of 20 samples.	Coefficient of variation.
		gms.	
Werribee R1—native grassland	26	360	70
Werribee R2—cultivated	91	1,250	60
Merrigum 1—permanent pasture	32	330	61
Wimmera BP4—native grassland	25	1,210	50

General Discussion.

The first purpose of this investigation is to obtain some numerical expression which indicates the desirability of the structure of the soil under test. In order to show the extent to which this has been achieved Table VII has been compiled showing the values obtained for several soils by three of the tests described in the preceding section, together with the percentage of organic carbon (representing about 58 per cent. of the total organic matter) as found by the rapid approximate method of Tiurin (1931). The several samples have been classified into four groups in order of merit. The basis for this division (which at best must naturally be somewhat arbitrary) is the local reputation or the farmer's opinion or description of the behaviour of the particular soils.

The percentage disaggregation as determined both for material less than 0.25 mm. and 0.07 mm. diameter, gives a good correlation with field behaviour, as shown in figs. 1 and 2. It appears that these two proposed methods will be distinctly useful in further work on soil structure.

There are a few cases in which the field rating disagrees with laboratory analysis. Two grassland soils from Werribee, which

TABLE VII.—SHOWING PERCENTAGE DISSAGGREGATION AS DETERMINED BOTH BY THE MEYER APPARATUS AND ALSO HYDROMETER METHOD ALONG WITH PERCENTAGE ORGANIC CARBON, APPARENT SPECIFIC GRAVITY.

Soil and Treatment.	Percentage disaggregation.		Apparent Specific Gravity.	Organic Carbon.
	< ·25 mm.	< ·07 mm.		
Group I.—First Class Structure.				
Kerikeri clay	8	..	..	4·23
Penola black clay	23	16	..	5·35
Berwick black clay—under permanent pasture	5	18	0·80	4·10
Dookie red loam—under cultivation ..	33	51	..	1·71
Trentham red loam—virgin forest soil ..	31	22	..	1·16
Wimmera BP4—native grassland	25	24	1·13	1·50
Merrigum 2—lucerne for many years, then 4 years sown pasture	32	..	1·24	1·94
Merrigum 1—natural pasture—greatly improved—much subterranean clover ..	32	67	1·24	2·14
Group II.—Good Structure.				
Merrigum 7—untouched native grassland ..	46	..	1·34	2·18
Werribee R4—native grassland	27	..	1·26	1·63
Werribee R1—native grassland	26	43	1·18	2·09
Rutherglen 3—under subterranean clover for 8 years, then cropped year before sampling ..	47	..	..	1·75
Werribee B—long cultivated soil, bare fallow	53	..	0·95	2·22
Wimmera BP1—native grassland	41	27	1·18	0·49
Wimmera BD3—native grassland	54	52	1·48	0·73
Wimmera BD6—native grassland	37	52	1·55	1·49
Wimmera B15—cultivated rough fallow ..	68	..	1·03	0·90
Wimmera BD16—native grassland	25	..	1·29	2·12
Wimmera B18—paddock which had just been cultivated for first time	45	..	..	1·12
Dookie black clay—long cultivated bare fallow	60	62	..	..
Group III.—Rather Poor Structure.				
Wimmera R8—native grassland	61	63	1·65	1·43
Wimmera R19—red patch occurring among black—native grassland	72	..	1·59	1·45
Wycheproof—from "red plains" country in Southern Mallee—native grassland ..	67	..	1·50	1·13
Wycheproof— from "buloke" country in Southern Mallee—native grassland ..	60	..	1·57	..
Group IV.—Bad Structure.				
Merrigum 4—orchard soil—much cultivated ..	96	..	1·34	1·26
Merrigum 5—orchard soil—much cultivated ..	96	71	1·46	1·41
Merrigum 6—wheat-fallow rotation for many years	91	64	..	1·21
Merrigum 8—cultivated for many years—reverted to native pasture in the last 2 years	82	..	1·67	1·30
Merrigum 9—cultivated for many years—reverted to native pasture in the last 2 years	88	66	1·66	1·46
Werribee R2—cultivated for many years ..	91	60	1·34	1·34
Werribee R3—long cultivated—treated with gypsum, three years previously	87	57	..	1·39
Rutherglen III. } cultivated for many years—various green manurial treatments	88	..	1·35	0·70
Rutherglen V.	87	..	1·33	0·96
Rutherglen VIII.	87	..	1·33	0·97
Rutherglen X.	90	..	1·35	0·63
Rutherglen 4—much cultivated paddock ..	69	..	1·35	1·04
Rutherglen 6—much cultivated paddock—said to be "worn out"	73	..	1·42	0·70

are placed in group II, appear by Meyer's method (fig. 1) to be better than they are. This effect is due to the way in which roots hold the particles together; when thse soils are shaken with water as in the hydrometer method the discrepancy disappears (fig. 2). Again, Merrigum 1, a soil which has never been ploughed, seems very good in the field but gives a poor figure after shaking (fig. 2). This may be due to the softness of the crumbs, and suggests that the soil deteriorates quickly under cultivation.

CORRELATION BETWEEN AGRICULTURAL REPUTATION AND PERCENTAGE DISAGGREGATION (MEYER APPARATUS)

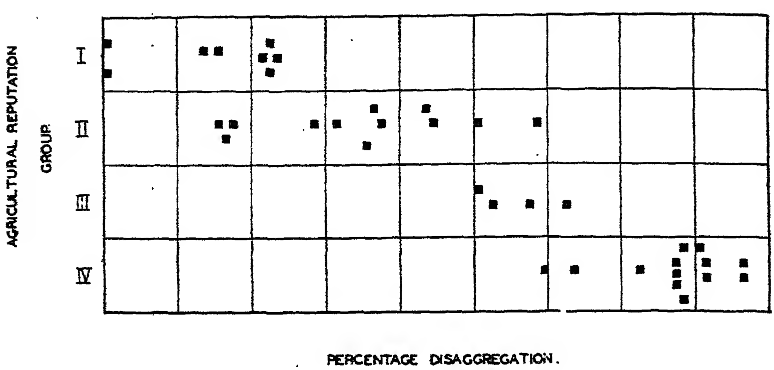

FIG. 1.

CORRELATION BETWEEN AGRICULTURAL REPUTATION AND PERCENTAGE DISAGGREGATION (HYDROMETER METHOD)

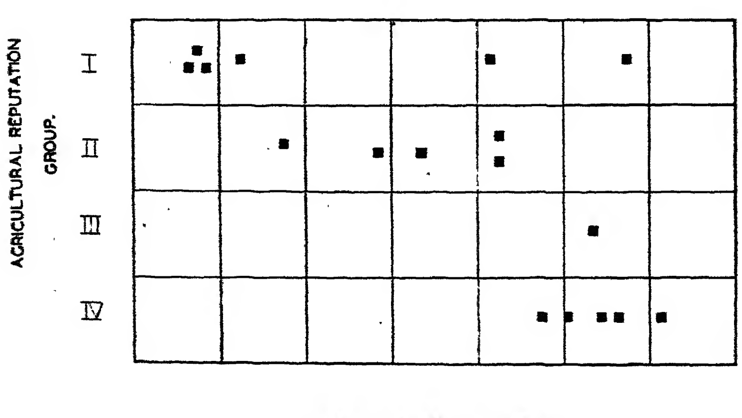

FIG. 2.

From the above discussion it seems to follow that for proper comparison of grassland soils with one another it is desirable to include a shaking treatment in order to form a judgment on the relative merits of such soils after a few years of cultivation.

The results obtained from the Meyer apparatus after various times of shaking and those obtained from the hydrometer method which involves shaking treatment, given in Tables III and VII respectively, form a reasonably sound basis by which the soil types may be classified. A soil having a low percentage disaggregation which alters very little after shaking has a very good structure. The amount of alteration on shaking is probably more important from the practical point of view than the initial percentage disaggregation for it represents what structure that soil may develop when subjected to agricultural practices. On this basis the soil types studied may be placed in order of merit as follows:—

Kerikeri clay loam
Penola black clay
Berwick black basaltic loam
Wimmera B "puff"
Trentham and Dookie red loams
Werribee R
Wimmera B "depression"
Merrigum.

COMPARISON OF STRUCTURE WITHIN TYPES.

Probably the most useful application of the measurement of structure is to show up the effects of various treatments on one soil type. Many workers both in Russia and America emphasize the damage to structure caused by cultivation. Bradfield (1937) likened cultivation to a surgical operation, meaning that it should be done only if absolutely necessary—it may do immediate good but in itself is bad. Cultivation is essential for the growing of crops, but a long succession of crop and fallow, without a period under pasture, is undesirable. The red soil at Werribee and certain types in the Goulburn Valley have deteriorated physically under cultivation. In the case of the Werribee soils it is said by some old residents that the deterioration is not only in physical condition but also in crop yields. The "black" soils of the Wimmera with a better natural structure than the two types already mentioned do not seem to have suffered at all.

From Table VIII it may be seen that each cultivated soil shows a greater percentage disaggregation than the respective uncultivated soil. Most of the cultivated soils studied have been farmed on a crop-fallow rotation and it can be seen from the table that they contain less organic matter than the uncultivated soils and in general have a higher specific gravity, except immediately after cultivation.

It is interesting to see how the application of gypsum to the cultivated Werribee soil only brings the density of the soil down to that of native grassland and has apparently little effect on the percentage disaggregation. The differences however were probably more marked two years earlier. Meyer's method is, of course, not suitable for soils which owe their virtue to flocculation by soluble salts.

TABLE VIII.—SHOWING THE DIFFERENCE IN STRUCTURE OF CULTIVATED AND UNCULTIVATED LAND.

Soil.	Treatment.	Percentage disaggregation. Meyer.	Percentage Organic Carbon.	Apparent Specific Gravity.
Merrigum 1 and 2	Improved pasture ..	32	2·04	1·24
" 7 ..	Virgin pasture ..	46	2·18	1·34
" 4 and 5	Orchard—much cultivated	96	1·33	1·40
Werribee R 1 and 4	Native grassland ..	26	2·09	1·18
" R 2 ..	30 years cultivated ..	91	1·34	1·34
" R 3 ..	30 years cultivated, treated with gypsum 2 years previously	87	1·15	1·15
Wimmera B ..	Native grassland ..	25	1·50	1·13
" B ..	Wheat stubble, August, 1938	44	..	1·07
" B ..	Under wheat crop, August, 1938	58	..	0·99

The high specific gravity of some cultivated soils is due to the reduction of aggregates to finer particles which block up the non-capillary pore spaces. This effect of cultivation is not shown on Wimmera soils for it seems that such fine particles have the capacity to regenerate into aggregates of reasonable size within a short space of time. Investigations on plots at Longerenong under crop and fallow have shown that while under crop and not being cultivated the soil tends to regenerate its structure as shown by the results in Table IX. This is not the case with other soils such as Werribee and Merrigum types for on these soils the effect of cultivation is cumulative and the structure gets worse from year to year unless the land is allowed to revert to pasture for a few years.

The effect of pasture on the regeneration of structure has been described by various Russian workers. The beneficial effect of pasture on structure is due to two factors. Firstly, the chemically stabilizing effect of the rapidly decomposing organic matter according to Geltzer (1934). Secondly, besides any such chemical effect there is the mechanical effect of roots holding particles together which would otherwise have passed through a sieve. The relative importance of these two factors is as yet undetermined. Some of our figures also show the good effect of pasture. The Merrigum soil under pasture, a prominent component of

which is subterranean clover, can be compared with an orchard soil which has been constantly cultivated for many years. During the last few years weeds in the orchard have been encouraged in the winter and ploughed under during the spring in order that the increased organic matter might improve the soil both from the point of view of working and irrigating. The orchard soils seen just after a good cultivation gave a good impression and the subsequent poor results given by a Meyer analysis were rather surprising. The results were justified, however, for inspection of the orchard later in the year showed it to be badly

TABLE IX.—SHOWING REGENERATION OF STRUCTURE OF WIMMERA BLACK SOILS DURING A PERIOD OF 12 MONTHS AND ALSO THE DIFFERENCES IN STRUCTURE OF NON-FALLOW COMPARED WITH VARIOUS FALLOW PRACTICES.

—	Percentage Disaggregation (Meyer Apparatus).			
	Last cultivated June, 1938—prior to sowing.		Last cultivated June, 1937—prior to sowing.	
		Standard Error.		Standard Error.
Summer fallow ..	52·2	2·1	39·9	1·7
Winter fallow ..	50·3	2·1	43·4	1·9
Late fallow ..	49·2	2·1	..	..
Non-fallow ..	39·9	1·4	..	..

packed in spite of the green manurial crop which is ploughed in every year. The reason for green manuring orchard soils at Merrigum was to overcome the effects of bad structure. It is quite likely that green manuring although it cannot regenerate the structure of a soil having so much cultivation, does prevent any further deterioration. Our methods are not refined enough to measure such differences as green manuring may bring about on these soils.

GREEN MANURIAL TRIALS.

Structure analyses were done in conjunction with dynamometer trials on green manurial fields at Werribee in 1937 and 1938 and at Rutherglen in 1938. The plots were first laid down in order to compare the relative merits of the rotations: (*a*) wheat or oats alternating with a year of bare fallow; (*b*) wheat or oats alternating with a green crop sown in autumn and fed off in late spring; (*c*) the same as (*b*) with the green crop ploughed in during late spring. The results with Meyer's method on Werribee samples in 1937 showed that the "fed off" plots were slightly better than the "ploughed in" which in turn were better than those with the crop-fallow rotation. The records of the dynamometer also showed that the fallowed plots were the most refractory. In 1938 however the results were completely at random probably because the plots were very uneven both from the point of view of soil type and topography. At Rutherglen

in 1938 samples taken from the green manurial field showed no differences among treatments. The soil in this field is too variable for such a test to succeed.

WINDBLOWING OF SOIL.

The possibility that the "black" land of the Wimmera might be liable to blowing is suggested by its resemblance to certain areas in the North-American wheat belt which have suffered severely in recent years. Hopkins (1935) has pointed out that soils high in organic matter and lime have blown in past years in America. The Wimmera "Black" soil which is considered to be the best of the Victorian wheat belt has blown in previous years. It seems, however, that a certain set of conditions are required before anything of a serious nature occurs. It is only after a heavy fall of rain in the summer time followed by strong winds that the blowing occurs for then the top layer is disintegrated into small particles which dry quickly, before any regeneration can take place, into a light powdery layer. The blow can be prevented by working this thin layer into the soil as soon as possible after the rain; it is then able to regenerate its structure. We have examined drifts of blown soil and paddocks that have been blown and have found that as regards soil-structure one paddock is no more likely to blow than any other. It is obvious that the fineness of the natural structure is connected with the problem, for the crumbs of the Wimmera soils are very small. According to Hénin (1936) this property is to be expected of calcareous soils.

Deterioration and Regeneration.

It is obvious from the above discussion that structure is by no means a permanent property of the soil, but changes take place in some soils in the course of a few days and in others over a period of years.

By deterioration of structure we mean that the aggregates are breaking down into smaller particles thus blocking the pore spaces, or else the aggregates are losing their capacity to remain as separate individuals and are gradually merging into one another to form a compact mass, thus giving the same effect.

POT TESTS ON WERRIBEE SOILS.

This experiment was designed in the first place in order to check some surprising Russian work by Chizhevsky and Kolobova (1935), comparing the growth of a crop on soils composed of aggregates of various sizes. These were obtained from the red and black soils from Werribee already described (p.). The experiment was inconclusive as regards the relative growth of plants, but as a study of the effect of weathering on aggregates from good and bad soil types it is of interest. The soils were collected from the mulch of a fallowed field and air-dried, after

which each type was sieved into fractions of the following sizes, greater than 12 mm., 12–5 mm., 5–2 mm., 2–½ mm., and less than ½ mm. diameter. The four smallest fractions were placed in pots, 9 inches in diameter and ·30 inches deep, which had been sunk into the ground. Duplicate pots of each fraction (making the total number sixteen) were arranged in the formation of a randomized square. Oats were sown and harvested and with the exception of a general superiority of the yields of the black over the red no conclusive results were obtained. It was decided to leave the pots to stand for twelve months exposed to the weather and then determine the condition of the structure in the top 4 inches and compare this with the analyses done on the original materials. The results in Table X show that all fractions of the black soil have regenerated their structure to a certain extent while the red fractions have not changed significantly. The reason for the slight increase of the material greater than 4 mm. is due to the refractory nature of the clods caused by "packing." This material cannot be called genuine aggregates as in the case of Kerikeri and some other soils, for it becomes paste-like on the sieves and requires slight mechanical action to remove it. On breaking down it passes entirely through the sieves and merely increases the percentage of material less than ¼ mm.

Table X.—Showing Structure Analyses of Various Fractions of Werribee Red and Black Soils Before and After 14 Months Weathering.

—	Fraction.	Year.	> 4 mm.	4–1 mm.	1–¼ mm.	< ¼ mm.
Werribee Red ..	12–5 mm. ..	1937	1·9	3·8	12·5	80·8
		1938	7·3	4·0	13·0	75·7
	5–2 mm. ..	1937	2·0	9·4	11·9	76·7
		1938	8·1	4·3	8·4	79·2
	2–½ mm. ..	1937	..	5·3	21·5	73·2
		1938	3·5	2·1	12·4	82·0
	< ½ mm. ..	1937	..	..	8·1	91·9
		1938	1·8	..	6·2	92·0
Werribee Black ..	12–5 mm. ..	1937	10·1	11·3	27·7	50·9
		1938	6·7	19·6	35·9	37·7
	5–2 mm. ..	1937	8·2	33·7	25·4	32·6
		1938	19·9	24·8	13·6	31·8
	2–½ mm. ..	1937	..	7·1	43·8	49·1
		1938	4·5	13·2	46·7	35·7
	< ½ mm. ..	1937	..	..	30·6	69·4
		1938	33·2	2·3	22·9	42·6

Longerenong Plots.

The regeneration of structure has already been referred to in reference to the results from Longerenong as given in Table IX. The results show that there are no differences in structure caused

by different fallowing systems commonly used in the Wimmera. They do, however, show that after cultivation the percentage disaggregation is higher than at the end of the period during which the soil is under crop and stubble, thus showing that regeneration has taken place. It is only on such soils as these and the Werribee black type that constant cultivation can be carried on without after a few years encountering the difficulties attributable to bad structure. On other soils which do not show this regeneration such as Werribee red, Merrigum and Rutherglen, cultivation for a few years should be rotated with pasture for another period of years the length of which is as yet undetermined.

Summary.

Two methods of measuring the water-stable aggregates of soils are studied in detail and the correlation of these methods with field behaviour is discussed.

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Art. II.—*A Study of the Granulation of Some Commercially Milled Victorian Flours.*

By INEZ W. DADSWELL, M.Sc. (Wis.), and WINIFRED B. WRAGGE, M.Sc. (Melb.).

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Introduction.

When samples of flour from different flour mills in Victoria became available in 1936, it seemed an opportune time to record their granulation, especially since no general survey had been made of the granulation of wheat flour milled in Victoria. The Victorian Millowners' Association supplied the samples and a grant which made this work possible.

Wheat flour is a microscopic system containing particles of wheat endosperm ranging in diameter from 0.1μ to about 200μ. The particles are composed of starch granules of different sizes—accounting for about 75 to 90 per cent. of the total weight, a protein material called gluten—usually 8 to 20 per cent. and a small amount of cell wall. The starch granules are present in two forms—free and imbedded in the protein material. The protein is present in the aggregates of protein and starch granules. The number and size of the flour particles depend to a large extent on the milling operation.

The granulation of flour is important to both the miller and the baker. The miller is desirous of producing the flour as economically as possible, while at the same time retaining a high quality. He knows that the finer the milling products, the greater the cost of production, since more power is required for the reduction process, and fine flour requires a greater dressing or sieving surface because small particles are more difficult to dress. Quality may be affected by the heavy roller-pressure used in producing fine flours since this pressure is accompanied by elevated temperatures.

The baker judges flour to some extent by the "feel" of it and he considers the texture of the flour to be correlated with certain characteristics exhibited by the flour in the bakehouse. He is interested in the amount of water which must be used in making a dough, in the rate at which the dough develops and in the rate of gas production. It has been shown by Gründer (1935) that the fineness of a flour is related to both the rate at which water reacts with the flour when it is made into a dough and to the rate of gas production in the dough. Thus fine grinding may compensate to some extent for a low diastatic activity in the flour.

On the other hand, the same worker has shown that the elasticity and stability of the gluten are impaired by very fine grinding.

Two procedures are in general use by the miller for judging the fineness of flour. The first one is to feel the flour between the fingers. Variations between flours of very different granulation can be detected in this way but no record can be made of such variation except to describe the flour as "soft, medium, hard, smooth, gritty, &c." The "feel" of a flour is greatly influenced by the sharpness of the particles, not only by the size. Thus the final judgment is a composite of two characteristics, the shape and the size of the particles. It is obviously not possible to differentiate between them in the description of the "feel" of a flour.

The second method for judging fineness is to sift a sample of flour through a bolting cloth of known mesh size and note the proportion retained on the sieve. That this may be misleading has been shown by several workers among whom are Shollenberger and Coleman (1926). They found that flour which had been ground several times and was undoubtedly made finer by the process, sifted through a certain sized mesh less readily than did the same flour which was ground only once. Markley (1934) also found that the sieving method of estimating granulation is very inefficient. Thus neither of these methods, feeling it or sieving it, gives the miller or baker a satisfactory estimate of the granulation of flour.

Measurement of Granulation.

Methods for the estimation of the granulation of a powdered material such as flour may be divided into two groups—direct and indirect.

I. Direct Methods of Measurement.

The direct methods of measurement are of two kinds.

(*a*) *Sieve Analysis.*—Gründer (1932) pointed out that this method is only of use for particles of 60μ diameter or over. Inasmuch as the largest starch granules in Victorian flours are about 40μ in diameter and the finest mesh of bolting cloth has an opening of about 60μ, there can be no differentiation in size of starch granules by this method. In addition to the free starch granules all aggregates of starch and protein below 60μ in diameter would be free to pass through the finest mesh of silk bolting cloth.

By representing Markley's (1934) results for a commercial patent flour graphically, as in fig. 1, it is evident that up to 84 per cent. of such a flour is composed of particles having an equivalent diameter of 60μ or less and therefore a sieve having openings of 60μ diameter can differentiate only 16 per cent. of the total weight under theoretical conditions. Markley actually found,

by determining the granulation of flours of varying degrees of fineness by sieving and by sedimentation, that very much less than the expected amount is passed through a sieve, as the particles passing a fine mesh are all considerably smaller than the finest mesh through which they have passed.

Gründer (1937) found that a flour sifted so as to be retained on an 150μ mesh opening and to pass a 200μ mesh, may be made up of particles of which only 20 per cent. are greater than 150μ diameter.

Several workers have contributed observations on the sifting of flour. Shollenberger and Coleman (1926) found that finely ground flour bolted more slowly than coarsely ground flour. Van der Lee (1928) considered that the rubbing of the flour on the silk sieves generated electrical forces which were partially responsible for the abnormalities encountered in sifting flour. Micka and Vrana (1930) thought that the temperature and moisture content of both the flour and air, the load on the sieves and their motion as well as the time of sifting, all affected the results of a sifting test for granulation.

(*b*) *Microscopic Measurement.*—By this method particles of angular shape are difficult to measure and small numbers of measurements are inaccurate. The method is also very time-consuming.

II. Indirect Methods of Measurement.

The indirect methods of measurement are those involving sedimentation in a gas or liquid. Sedimentation by means of an elutriator is not practical for small quantities of material.

Sedimentation in liquids may be carried out according to several modifications. They are all based on Stokes' Law of falling spheres in liquids, which is—

$$V = \frac{2}{9} g\, r^2 \frac{(D_1 - D_2)}{\eta}$$

V being the velocity of fall; g, the gravity constant; r, the radius of the sphere; D_1, the density of the sphere; D_2, the density of the liquid which is in lyophobic relation to the particle and η, the absolute viscosity of the liquid.

In any one system, the radius of the largest particle being deposited at a given time is in inverse ratio to that time since—

$$V = \frac{h}{t}$$

h, being the height of fall and t, the time of fall.

Therefore $\frac{h}{t} = \frac{2}{9}\, g\, r^2 \frac{(D_1 - D_2)}{\eta}$

The results are commonly represented graphically by plotting the percentage deposited against the time.

(*a*) *Odén's Method of Weighing* (1916).—This method has been applied to flour by Markley (1934). He used a mixture of carbon tetrachloride and cleaner's naptha as the liquid in which to suspend the flour particles. One pan of an automatic balance was suspended in a dilute suspension of the flour and the increase in weight of the pan noted as the particles settled out. Markley obtained his data as accumulation curves. One way of interpreting such curves is to draw tangents to the curves at successive time intervals. The points where these tangents intersect the percentage deposited axis represent the amount of material in the system with radii larger than those defined by the time points used. This method of interpretation is slow. Markley used a method of calculation from the data collected in which q represents the quantity of particles of radius greater than that defined by the corresponding time t from the percentage deposited value P.

$$q_2 - q_1 = t_2 \left(\frac{P_2 - P_1}{t_2 - t_1} - \frac{P_3 - P_2}{t_3 - t_2} \right)$$

(*b*) *Sterckx Method* (1935).—By measuring the height of the sediment accumulated in a vertical cylinder at successive intervals of time, Sterckx has developed a method for flour mill control work. It is quick and does not require special skill for its use. Unfortunately, it cannot be interpreted in terms of absolute size of particles. Also it disregards the finer particles since the height of the column of sediment is proportional to the weight, only during the early part of the sedimentation.

(*c*) *Pipette Method.*—This method is another variant of the Odén technique. Instead of weighing the sediment as it settles out, samples are pipetted off from a suspension at a known depth and time. The amount of flour in the aliquot is then determined. Gründer (1932) applied this method to wheat and rye flours. He suspended 10 grams of flour in 535 ml. of diethyl phthalate. 10 ml. samples were taken at known depths and times after the sample had been vigorously agitated.

He encountered some difficulty with the entrapped air after shaking due to the high viscosity of the diethyl phthalate. The suspended material in each pipetted sample was filtered off into a fritted glass crucible having pore openings of 5 to 10μ, washed with ether to remove the diethyl phthalate, dried at 40–50°C. and weighed. The percentage in suspension at each given time was calculated and the difference between those values and 100 is the amount that had settled out. For a given time and depth the largest particle to settle out can be calculated from Stokes' law and such values for diameters are plotted against the corresponding percentage of material settled out. To determine the amount of flour in a certain size range it is only necessary to consult the graphical representation of results.

The high viscosity of the solution used, causing entrapping of air seems at first to be the main disadvantage of this method.

(*d*) *Turbidity Measurement.*—Because the pipette method is slow, Gründer and Sauer (1937) developed a quicker method for plant control work, in which the turbidity of a suspension could be observed with a photoelectric cell. This method depends on the relation between light absorption and size of particle. They found that for the range studied (about 70μ to 200μ diameter) in the system of wheat flour in diethyl phthalate, the light absorption was practically independent of the size of particle. However, apparently measurements were not made for particles of low diameter and in fact these workers neglect the sedimentation of particles of less than 30μ diameter. They state that about 80 per cent. of the flour is made of granules which are about 40μ in diameter.

In Australian flour it is desirable to measure a greater range of sizes than Gründer and Sauer did by means of the photoelectirc cell method.

(*e*) *Separation of Flour Constituents on Basis of Density.*—Gründer (1934) has separated wheat and rye flour into their component particles by means of mixing them with solutions having different densities. For this purpose he used varying amounts of xylol, carbon tetrachloride and dichlorethylene to obtain densities ranging from 1.42 to 1.60. By centrifuging the flour with a solution of density 1.46 to 1.48, the flour was separated into two fractions. The floating material consisted of bran particles and practically all of the protein containing particles. The sediment consisted of almost pure starch with a trace of impurities such as sand, &c. These two fractions were further subdivided by repeating the centrifuging with liquid mixtures of other densities. This method of separation does not give information on the particle size but it might be used as an indication of the degree of grinding since very fine grinding will liberate more starch, which will in turn be separated by this method.

(*f*) *Surface Area by Witte's Method* (1936).—Information as to the surface area of a powder is an indication of its fineness. Witte mixed small amounts of flour with coal dust in definite proportions and noting the percentages of black and white in the mixture by means of a Leukometer, a number proportional to the surface area of the flour can be obtained The method is relatively quick to carry out but it has the disadvantage of masking any unusual mixture of fine and coarse particles such as would be revealed by a sedimentation curve.

Experimental.

In carrying out determinations of the particle size of flours milled in Victoria, a modification of the Robinson (1922) pipette method as applied to soils was used. The flour was suspended in a mixture of two parts benzene and one part of carbon tetrachloride by weight. This mixture has a fairly constant viscosity which is low enough so as not to entrap air. The viscosity and density of the solution were determined for the temperature at which the sedimentation took place. It was possible to follow the sedimentation to a point where only 5 per cent. or less remained in suspension.

25 grams of air-dry flour were placed in a thick glass bottle and 200 ml. of benzene carbon tetrachloride mixture were added. The stoppered bottles were shaken for three hours. Then the contents were poured into a cylinder $2\frac{1}{2}$ inches in diameter, having a capacity of 1,250 ml. and the volume made up to 1,200 ml. at 15°C.

20 ml. aliquots were withdrawn at varying times and depths after the suspension had been thoroughly mixed. The aliquots were placed in small tared florence flasks, the liquid distilled off on a water bath and the flasks and contents dried and weighed. Sedimentations were carried out in duplicate in a constant temperature cupboard at 15°C.

The average density of the finest and coarsest samples of flour was determined by placing a known amount of the flour in a pycnometer and filling the pycnometer with the benzene-carbon tetrachloride mixture of known density. The volume of the flour could then be determined and its density calculated. The average density was found to be 1.476 ± 0.006.

Knowing the average density of the flour particles and the density and viscosity of the liquid, by means of Stokes' law, the equivalent radii of the flour particles were calculated corresponding to different falling velocities.

From the percentage in suspension, the percentage deposited may be calculated and plotted against the corresponding equivalent radius of particle. The curves No. 55, 31, 27, and 58 in fig. 1 were obtained in this way.

Knowing the radii and having summation sedimentation curves as in fig. 1 for each sample, the surface area exhibited by 1 gram of each flour may be calculated. In Table I. the surface area of 1 gram of flour is tabulated for each flour examined. Instead of recording the surface area as square centimeters per gram of flour, one may construct summation curves (fig. 2) based on surface area instead of on weight. Such a representation emphasizes the extraordinary influence which the small granules have on the total surface area.

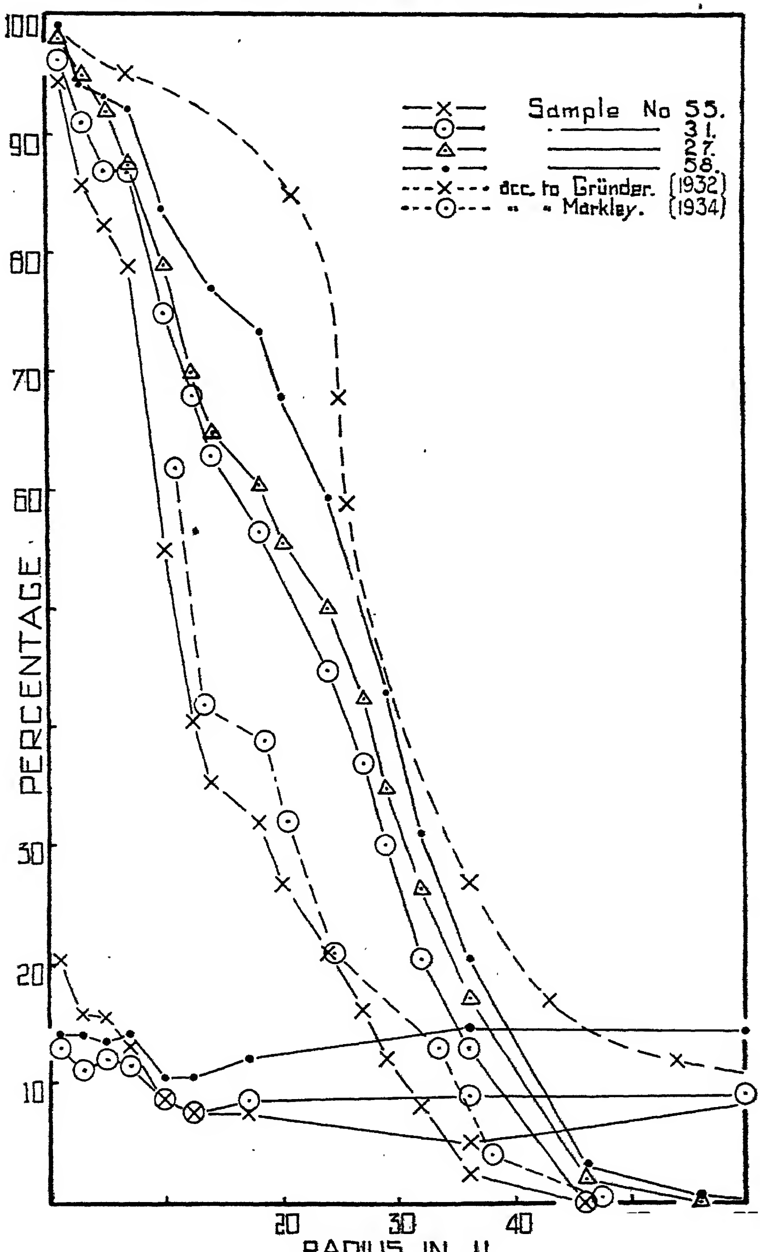

FIG. 1.—Summation curves illustrating the granulation of six samples of flour and the corresponding protein content of different size fractions for three of the samples.

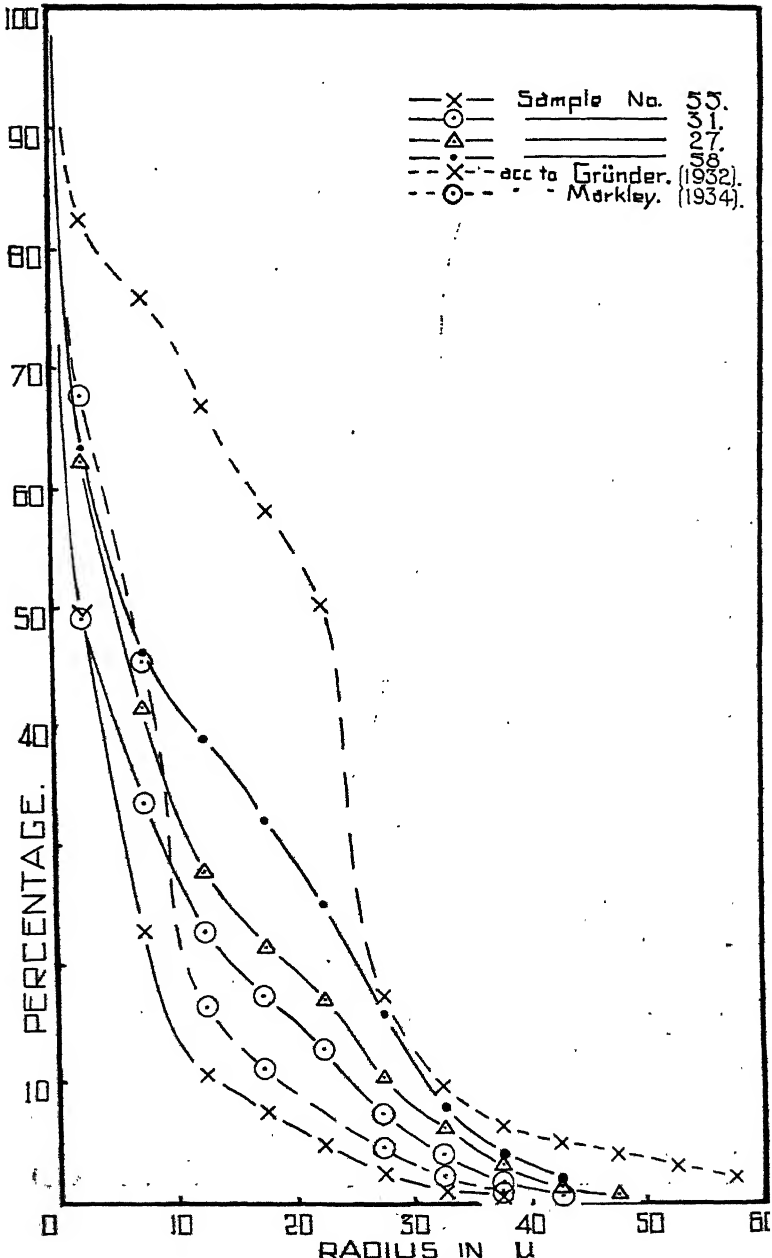

Fig. 2.—Summation curves illustrating the percentage distribution of the surface area in relation to the radius of particle for six samples of flour.

The nitrogen content of the 20 ml. aliquots was determined by the Kjeldahl method for three flours. The protein values (N x 5.7) obtained for a finely ground flour of low protein content (No. 55), a coarsely ground flour of high protein content (No. 58), and a moderately coarse flour of low protein content (No. 31) are shown together with their granulation curves in fig. 1.

A description of the flour as to the constituent wheats used, protein content, surface area per gram, and the percentage by weight above 20μ radius are given in Table I.

Discussion.

Fig. 1 gives a series of six summation curves. Three of them are for Victorian flours, one for a Canadian flour, and two from the literature for comparison. The three curves given for the Victorian flours represent the finest (No. 55) and coarsest (No. 27) flours in the collection of twenty-three samples as well as one (No. 31) of moderately coarse granulation. The Canadian flour (No. 58) was milled in Canada from Manitoba hard wheat and was imported into Australia for use in comparative baking tests. One curve represents graphically the results as published by Markley (1934) for a patent flour of commercial origin milled in America from hard spring wheat, and the remaining curve, the granulation of a wheat flour of usual commercial superfine quality in Germany according to Gründer (1932).

It is readily seen that all the flours from Victoria are finer than the Canadian flour represented in fig. 1, but the sample examined by Markley lies within the range covered by the Victorian samples. The interpretation of the curves as to size of particle is very dependent on the specific gravity of the flour. Markley does not indicate what value he used for the density of the flour. Gründer does give this value as 1.4000 in one paper (1932) and as 1.458 in another (1935). In still another place (1934) he indicates a method of separation of flour into two portions with a solution whose specific gravity was 1.46 to 1.48, such that 64 per cent. of the flour is in the floating portion and 36 per cent. in the heavier fraction, the latter being mainly free starch granules.

It is to be expected that Gründer's results will differ from those obtained in this investigation, since he was working with flours milled under different conditions and he was using a different density value for the flour with which he worked. The main difference between the granulation curve for a commercial flour obtained by Gründer (1932) and that obtained by Markley (1934), as well as those obtained in this investigation, lies in that portion of the curve for the particles of low radii, i.e., below

30μ radius. An explanation of the probable reasons for the difference in the two types of granulation curves will be given elsewhere.

Taking the percentage with radius above 20μ as an indication of the relative coarseness of the flour (see Table I.), 65 per cent. of the Victorian samples are made up of particles in which 40 per cent. or less are above 20μ radius. The remaining 35 per cent. of these Victorian flours contain 40 to 55 per cent. of their total weight as particles of radius greater than 20μ. 68 per cent. of the Canadian sample is made up of particles of greater than 20μ radius.

The percentage of protein in the suspended material rises slightly as the sedimentation progresses with the finely ground flour, but it remains more nearly constant in the coarsely ground flour (see fig. 1). This alteration in protein content of the suspended material indicates that fine grinding allows of the liberation of more of the starch from the protein material, at the same time particles of higher than average protein content are freed, and these remain in suspension longer because of their slightly lower density. It is evident that the use of an average value for density of the flour particles over the whole range of sedimentation will not lead to very serious error in interpretation of the sedimentation curves.

The curve showing the relation between the equivalent radius and the summation of the surface area of the particles (fig. 2) is a better indication of the fineness of a flour than the curve showing the summation weight or sedimentation curve in relation to the radii of the particles as in fig. 1. For certain purposes such as comparing the fineness of different flours, the surface area of 1 gram of flour in square centimetres is very useful. Such values from Table I. for the 22 samples of Victorian flour were used in compiling the frequency data in Table II. The values for surface area per gram of flour give a normal frequency distribution.

Theoretically, in forming a dough by addition of water, intimate contact between flour particles and water should be achieved in less time in a finely ground flour than in a coarsely ground one. Likewise, the contact between added dough improvers, yeast, &c., and the flour would be more readily established in finely ground flour. Gründer (1935) has furnished experimental proof of the correlation between fineness of a flour and both the dough developing time and the rate at which carbon dioxide is generated in the dough. By the use of the Brabender fermentograph and farinograph apparatus he was able to show that as the surface area of a given flour increased, so the carbon dioxide produced increased and the dough developing time shortened. In controlling the quality and uniformity of his product, this is of direct use to the flour miller. The control of

granulation may be achieved either by mixing flours of known granulation or by controlling the grinding and dressing of the flour from a given blend of wheats.

TABLE I.

Sample No.	Mill.	Percentage above 20 μ radius.	Surface area in cm^2 per gram of Flour.	Percentage Protein on dry basis.	Description of Sample.
58	N	68·0	1,504	14·1	Manitoba hard wheat
27	C_2	55·6	1,705	16·3	"Strong" flour
34	H	53·0	1,949	8·9	"Dundee" and "Baringa" wheat from South Riverina, N.S.W., and "Ghurka," "Ranee," and "Waratah" from Rutherglen and Wangaratta
23	B_2	48·0	2,023	8·5	"Ghurka" from Rupanyup District
31	E	52·0	2,065	9·1	"Dundee" wheat from Charlton District
22	B_1	41·0	2,135	11·4	Blend of Mallee wheats
32	F	47·0	2,147	9·4	"Ford," "Baringa," and "Dundee" wheat from N.S.W. (41 per cent.); 1934–35 wheat from Waaia District (mixed) (17 per cent.); 1935–36 wheat from Katamatite and Waaia Districts (mixed) (42 per cent.)
28	D	41·5	2,148	9·7	Wheat from Riverina and Victorian Wimmera Districts
29	D	41·5	2,230	9·7	" " " " "
26	C_2	39·5	2,256	11·3	"Medium" strength flour
36	J	39·0	2,284	10·8	"Ranee 4H" wheat with small amounts of "Free Gallipoli" and others. Wheat from 3 seasons—⅓ 1933–34, Millewa District; ⅓ 1934–35, Walpeup District, and ⅓ 1935–36, Millewa District
24	C_1	40·0	2,292	11·1	
25	C_2	37·0	2,300	9·6	"Weak" flour
35	I	39·0	2,313	9·9	Mainly "Ranee" and "Ghurka" with mixture of premium wheats (no Gallipoli used) from Northern and Mallee Districts
30	E	35·0	2,350	10·0	50 per cent. from Charlton District, 30 per cent. from Stations north of Charlton, and 20 per cent. from Stations on Ultima Line
38	L	36·8	2,358	9·8	
21	B_1	38·0	2,359	12·5	Blend of specially selected "strong" North-west Mallee and Riverina wheats
37	K	37·0	2,363	10·8	
20	B_1	35·5	2,367	11·1	Selected Victorian wheat of f.a.q., quality
33	G	30·5	2,567	9·7	Mixed varieties grown in Wycheproof, Murrayville and Donald Districts
54	C_1	32·5	2,590	10·3	"Strong" flour
53	C_1	29.0	2,682	12·4	"Extra strong" flour
55	C_1	26·7	2,784	8·7	"Weak" flour
Mean of Victorian Samples ..		39·7± 9·7	2,284± 242	10·5± 1·6	

Of the samples of Victorian flour examined, the surface area per gram of the finest sample (No. 55) is 63 per cent. greater than that of the coarsest sample (No. 27). These two samples differ widely in their protein content, the coarsest sample being higher. In contrast, two samples (No. 55 and 23) having an almost identical protein content differ in their granulation such

that the finer (No. 55) has a surface area 35 per cent. greater than that of the coarser sample. In considering all the samples examined there is a significant correlation of —0.538 between protein content and granulation.

TABLE II.

Area in sq. cm. per gram of Flour.	Frequency.
1,700–1,899	1
1,900–2,099	3
2,100–2,299	7
2,300–2,499	7
2,500–2,699	3
2,700–2,999	1

With differences in surface area per gram of the magnitude indicated in Table I., one might expect that such differences would be reflected in the bakery and no doubt those differences which do exist are partially bound up in the flour granulation.

For wheat of a given quality for a given purpose, it seems probable that there is an optimum granulation, just as there is an optimum diastatic capacity, protein content, &c. As yet very little is known about connecting the granulation of a flour with its properties except for the work of Gründer on flour milled in Germany.

It is to be expected that wheat of different varieties, grown in different places, may yield a flour of varying granulation when milled in different flour mills. If, however, the wheats from various sources were milled under uniform, set conditions, the granulation of the flour might be an indication of certain characteristics of the wheat from which it is made. Cutler and Brinson (1935) have found that by grinding whole wheat under uniform conditions, the resulting granulation is an indication of the class to which the wheat belongs, soft, medium, or hard, and the granulation number determined by them is correlated with the percentage of starchiness—a high proportion of fine particles being positively correlated with a high percentage of starchiness.

Further work carried out by Fifield (1934) of the United States of America Department of Agriculture indicates that the granulation number is correlated with the protein content of the grain and to a certain extent with the locality where it was grown.

Now the grinding of whole wheat meal is a different process from the grinding of wheat into white flour, but if there are inherent properties in the wheat kernel which affect the granulation number, one would expect that there would be some evidence of those properties exhibited in the grinding of wheat into flour.

If the setting of the rollers in the flour mills and the dressing processes were similar in the different mills, the flour produced might be expected to reflect that uniformity in production by varying in granulation according to the wheat used. As the granulation of the flours examined does not reflect such an indication of quality as the protein content, one can only conclude that the granulation of the commercial flours examined is almost solely the result of the varying opinions of the flour millers as to what constitutes a desirable granulation superimposed on the inherent properties of the particular blend of wheat which they have at hand for milling.

One must also infer that it is very unwise to draw any conclusions as to the quality of a flour from the "feel" of it for the granulation of these commercial flours in Victoria show no relation to one of the common measures of quality, namely the protein content.

It is of interest to note that certain Victorian flour mills tend to produce a flour of fairly uniform granulation irrespective of the protein content of the flour. This is true of samples from mills B_1, B_2, and D. (Table I.).

Other mills, E and C, produce flours of varying granulation and with different protein content, there being no relation between the protein content and the granulation of the products of the individual mill.

Since this paper was read the authors have learned of the work on Flour Granularity carried out by D. W. Kent-Jones, E. G. Richardson and R. C. Spalding, which was reported in the *Journal of the Society of Chemical Industry*, Vol. 58, pp. 261-267, August, 1939.

Summary.

The difficulties and inaccuracies encountered in estimating the granulation of flour particles by feeling the flour between the fingers and by sieving have been enumerated.

Other methods for the measurement of flour granulation have been discussed. The sedimentation method used in this investigation has been described and the results obtained when it was applied to 22 samples of commercial Victorian flour and one of Canadian flour are described.

It has been pointed out that there is a low but significant correlation in these commercial flours between quality as revealed by their protein content and granulation.

Because of the differences in both the blending of the original wheats and in the milling practice followed by the various millers, it is to be expected that the granulation of the samples will not be closely related to such a quality estimate as that furnished by protein.

Acknowledgments.

The authors are indebted to Professor W. J. Young and Professor S. M. Wadham for their interest and assistance throughout the work, and to the Victorian Millowners' Association which provided the samples and a grant for one of us. (I.W.D.).

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ART. III.—*The Biology of the Silverfish,* Ctenolepisma longicaudata *Esch. with Particular Reference to its Feeding Habits.*

By EDER LINDSAY, B.Agr.Sc.

[Read 13th April, 1939; issued separately, 1st March, 1940.]

Contents.

I. Introduction.

Ctenolepisma longicaudata was first described by Escherich in 1905 from material collected in South Africa. It has since been found in Palestine, Seychelles, and the New Hebrides, and the first record from Australia was made by Silvestri in 1908 from material of the 1905 Hamburg expedition. It is widely distributed in Australia and collections have been received from all the coastal regions, as far north as Cairns, and as far inland

as Broken Hill. During the last fifteen to twenty years it has become a household pest of economic importance, and in 1935 investigations into its control were undertaken by the Commonwealth Council for Scientific and Industrial Research. The work carried out at the School of Agriculture of the Melbourne University started as an inquiry into the attack upon wallpapers; but the control measures which were evolved necessitated the study of the insect's biology with particular reference to the reasons for its food preferences, and the extent to which it is affected by climatic conditions.

II. Experimental Methods.

Silverfish have a long life cycle. They reach sexual maturity in two to three years, and continue to grow for about five years longer, moulting three to five times each year. As it was necessary to use adults for the feeding tests, insects were collected in various buildings, mainly at night, and stocks of these were held in lots of one hundred in 200 cc. glass beakers, and were fed on tissue paper, gummed paper, artificial silk, and ground whole wheat and yeast. The beakers were kept in a cupboard in which a high humidity was maintained by open tubes of water, since previous tests had shown that in dry conditions, as, for example, in open containers on the bench, the insects died within one month. These conditions proved satisfactory for reproduction and growth. Cotton-wool was provided as a nidus for egg laying and facilitated the collection and removal of the eggs. Nymphs were reared on the same food as the adults.

In the tests on the food preferences the materials to be compared were subjected to the attack of twenty to forty silverfish held in a Petri dish containing two pieces of each material. As soon as the attack showed, the edible materials were removed, so that the silverfish were confined on the remaining pieces under semi-starvation conditions. In this way, any variation in the feeding stage of the various individuals was eliminated, and the tests were sufficiently rigorous to ensure that the materials would be attacked if at all edible. The pieces were folded so that the insects had easy access to all the materials. The whole series was duplicated. All were held in closed tins with tubes of water and kept at 24°C. for the two to three months of the test.

In the tests on wallpapers, the insects were confined on the surface of the sample by pushing the piece to the bottom of a 1-inch glass vial. Three silverfish were used on each sample. The tests were duplicated and the results were confirmed by subjecting selected samples pasted on glass to the attack of eighty silverfish. A section of these samples is shown in pl. II, fig. 2.

III. Feeding Habits.

Observations during the past three years have shown that silverfish, even the 2nd instar nymphs, range far in search of food, and include both animal and plant remains in their diet, as well as materials of economic importance such as paper and artificial silk. They are easily disturbed and are seldom observed eating; but at various times, they have been found indoors feeding on a variety of materials including bread crumbs, a dead moth, a piece of dried grass, and a fragment of the thorax of a beetle in which the muscles were still fresh.

1. Crop Contents.

Further information about the nature of the substances which are included in the normal diet, was obtained from an examination of the crop contents of more than sixty insects which were collected in various buildings.

The origin of the large fragments could be determined from their structure, and some of the stages of decomposition were identified by comparison with the crop contents of silverfish which had been given a diet of grass, paper, wool, cotton or artificial silk. The staining reaction of the fragments was tested with Iodine, Sudan III, Phloroglucin and Hydrochloric acid, Herzeberg's stain, and Lieberman's reagent. Herzeberg's stain was particularly useful for showing the presence of cellulose derivatives even after the structure of the plant cells had been completely destroyed.

Usually the crop contained material from one source only. Evidently the silverfish made a large meal from any edible material which it discovered. Insects collected indoors had frequently been feeding on plant tissue a short time previously. Many fragments found in the crops were so large that the epidermis and the cortical and vascular tissue could still be distinguished (pl. II, fig. 1B). The epidermis with stomata and hairs, and the vascular tissue with thickened and pitted walls were easily recognized. In many cases the cells still contained chloroplastids, and even after these had been broken down, the green colour of the chlorophyll persisted in the crop for some time. Many other groups of cells with various kinds of thickening could not be identified.

The fragments in many crops resembled those found among plant debris. Sand grains and pollen grains (pl. II, fig. 1A), Protococcus in both active and resting stages, and fungal spores and hyphae could be recognized (pl. II, fig. 1c). In some cases the hyphae were still living, and in one case the spores of *Ustilago hordei* were identified.

Four of the crops examined were almost completely filled with starch grains. One of these insects had been collected from a decaying tree, but the source of the starch could not be located.

Insect remains form part of the diet, and frequently setae, pieces of chitin (pl. II, figs. 1D and F), scales and tracheae were found in the crop. Animal hairs were found in only two of the crops.

In view of the varied nature of the crop contents it was interesting to see to what extent the dust of the room was a potential source of food. The dust was collected with a vacuum cleaner from behind the skirting boards and window frames of two lecture rooms. On examination the following materials were found; crumbs, small cellulose fibres, both single and in masses, woody fragments, insect legs, feelers, and claws, fragments of leaves and dried grass, string and sawdust. Even dust, it would seem, provides a varied diet for the insects.

2. Range of Materials Attacked.

To find the range of substances the silverfish would eat, various materials were subjected to the attack of groups of five insects for two months, no food other than the material under investigation being provided.

Artificial silk and cotton fabrics were readily eaten. Wool fabrics were generally not damaged, although occasionally a few fibres were found in the crop. Wool felt, flannel, carpet, fur felt, and natural silk were not damaged.

Attack on materials which were otherwise unpalatable, could be encouraged by smearing them with a palatable mixture of sweetened flour paste. In the course of the removal of this layer some of the fibres of the material were eaten, and occasionally the attack extended deep enough to damage the fabric. The unpalatable material, e.g., wool, silk, or sawdust was slowly digested. In the crop the fibres of wool were broken transversely into short lengths, the epidermal sheath flaked off, and the cortical cells frayed at the ends of the fragments. The cortical cells were apparently digested, for few were found in the hind intestine, though short lengths of the undigested fibres were sometimes found there.

3. Food Requirements of Adults and Nymphs.

Although the silverfish is normally an active feeder it can survive long periods without food. An experiment was made with twenty adult insects in separate containers (1-inch glass tubes). The first died after 21 days, and the others followed at intervals, the last three living 252, 276, and 307 days respectively.

A diet of cellulose alone was sufficient to support a longer life. The death rates of twenty adults fed only with filter paper were noted and in this case the last three insects lived 449, 576, and 636 days respectively.

A more adequate diet is necessary for the nymphs. Four groups each of twenty newly hatched nymphs were kept on various diets. The first group was given no food and eighteen survived the first ecdysis, but died early in the second stadium. The second group was given paper and flour. Eighteen of these insects survived the second ecdysis but died during the third stadium. The remaining two in both groups ate the dead bodies and cast skins of the others, and survived to the fifth instar. The third group was given paper, flour and casein. Most of them survived until the fourth and fifth instars, and only one of the dead bodies was eaten. The fourth group was given ground wheat and yeast in addition. Apparently this made an adequate diet, for on this the nymphs have been reared for eighteen months.

On the inadequate diets the food reserves were depleted by metabolism and ecdysis. The fat content of adults starved, or fed with cellulose, was reduced from 20 per cent. to 7 per cent. Normal silverfish contain 9 per cent. nitrogen. The cast skins, which weigh 5 per cent. of the dry weight of the body, contain 6 per cent. fat and 11 per cent. nitrogen, so that, with each cast skin 1 per cent. of the fat and 6 per cent. of the nitrogen of the body is lost. (These analyses were very kindly carried out by Mr. G. Ampt, of the Chemistry Department of the Melbourne University.)

4. Taste.

Silverfish are sensitive to the taste of certain substances even when these form only a small part of a mixture. Their behaviour suggests that the labial palps are the organs most sensitive to taste, the sense being probably located in the small papillae which occur on both sides of the tip (fig. 1c).

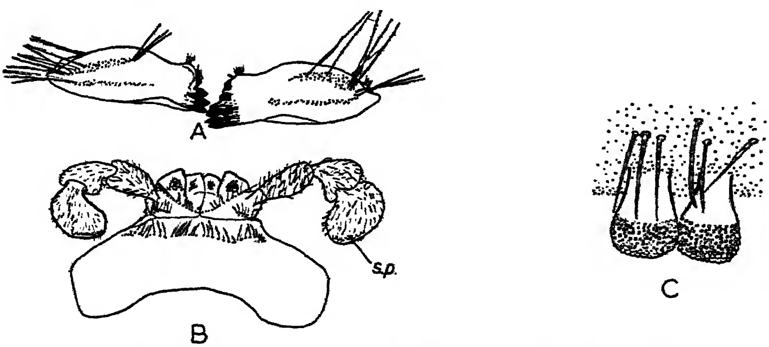

Fig. 1.—*A*. Mandibles. *B*. Labium × 14. *C*. Sensory papillae of labial palp × 300. *s.p.* sensory papillae.

The action of the mouth appendages during feeding was watched on silverfish confined in an optical cell $3\frac{1}{2}$ inches square and $\frac{1}{2}$ inch deep. The ventral side of the head was observed by means of a tilted mirror. Small heaps of powdered materials,

viz., flour, ground sugar, casein, fine chalk, and crystallized sugar were placed about $\frac{1}{4}$ inch from the edge. As the silverfish under observation moved about, it came into contact with the powder. This was touched first by the antennae, then by the maxillary palps, and then by the labial palps. The antennae and maxillary palps seemed to behave in the same way towards all the powders; but the labial palps immediately "scooped" the palatable powder, ground sugar, towards the mouth. The other powders were frequently touched by the labial palps, but the flour and casein were only occasionally pushed into the mouth. No attempt was made to eat the chalk or the crystallized sugar. The grains of the latter were probably too large.

The scooping action of the labial palps is characteristic; the expanded terminal segments act as "shovels" and push the material towards the maxillae (fig. 1B).

The labial palps are able to detect the palatability of the material before it is eaten. This sensitivity may be assisted by fluid from the mouth, for on some of the wallpaper mixtures (see below) there was a "water mark" of concentrated colour around the teeth marks and on certain parts of the undamaged surface. The "water mark" showed only on mixtures containing dextrin, and tests with droplets of water showed that only in these mixtures is the pigment held in such a way that a water mark will remain.

On a hard surface such as that of wallpaper, the mandibles (fig. 1A) are worked with a scraping movement. The mandible on the left side, which lies ventral to that on the right side, takes a wide sweep and scrapes towards the centre. These scrapings are then gathered by the right mandible, and, together with the small amount it accumulates itself, are pushed into the mouth. The scraping marks of the teeth can be clearly seen at the edge of the damaged parts (pl. I, fig. 2).

On a fibrous surface such as that of textiles and paper, the laciniae tease and lift the material towards the mandibles which chew through the connecting strands (pl. I, figs. 3 and 4). The pieces of fabric removed in this way are sometimes so large that the mesh can still be seen on the fragments in the crop.

Owing to this sensitive taste different kinds of such goods as wallpaper, writing paper, and artificial silk are attacked to different extents.

Wallpaper:—The effect of the different ingredients in wallpaper was tested on more than 9,000 sample mixtures.

The palatable materials in wallpaper are the various sizes mixed with the pigment and filler. The sizes used are starch, dextrin, casein, gum and glue. Only the mixtures containing starch and dextrin were extensively attacked, the colour being removed from the surface of the paper before the paper itself

was eaten (pl. II, figs. 2 and 3). The mixtures containing casein were eaten to a small extent, and as the insects did not continue feeding around the areas first attacked, only small areas of colour were removed. The mixtures containing gum and glue were not attacked unless the paper beneath was exposed at a scratch, and then the colour was removed as the paper was eaten.

All the sizes, even the apparently unpalatable gums and glues, were readily eaten when dissolved and dried into a thin layer on the surface of paper, so it is rather difficult to understand why the colour mixtures containing gum and glue proved so unpalatable.

Black, yellow, red and blue mixtures were tested, but the nature of the pigment had little effect on the extent of attack, except, perhaps, that it was rather slower on the black and yellow mixtures. The addition of filler lowered the percentage of size in the mixture and decreased the palatability.

It was interesting to watch the behaviour of a silverfish presented with pieces of both palatable and unpalatable wallpaper. The insect was held in a petri dish, and during its wanderings it walked over the surface of the unpalatable wallpaper several times. Then it touched the palatable wallpaper and immediately started to feed continuing for three hours, with only eight pauses of one to two minutes each. During the next hour it moved about the dish, walking over both the papers. Every time it walked over the palatable colour it took a few bites, but only twice did its jaws move when it was in contact with the unpalatable wallpaper, and even then no marks were made on the surface.

The paste used for fixing the papers to the walls was readily eaten when exposed at joins, but did not influence the attack on the surface. It had been thought at the outset of the investigation, that this paste attracted the silverfish to the wallpaper.

Writing, Printing and Wrapping Papers:—It was frequently noticed that only some of the sheets in a pile of papers suffered extensive damage; but that subsequently, all were readily eaten when the silverfish were confined on the papers. This localized attack could not be attributed to the position, for adjacent pieces of similar paper were attacked to different extents. Rather, it seemed that once the silverfish had made an attack, they tended to continue feeding there, with the result that the damage was concentrated in a few particular places.

The extent of attack was determined also by the nature of the paper. A wide range of papers, paper boards and paper pulps was tested. Mechanical pulp was not attacked, Kraft and Esparto pulps were slightly attacked, but bleached and unbleached sulphite pulps were readily eaten. A consideration of the nature of the pulps in the tested papers showed that all the papers which were readily eaten consisted of 100 per cent. chemical pulp, the

degree of attack depending on the finish and fillers used. The papers only slightly attacked, including "writing" paper, newsprint, and other printing papers, contained mechanical as well as chemical pulp.

This unpalatability of the mechanical pulp influenced the attack on the surface of wallpaper. The papers used in the tests contained 100 per cent., 52 per cent. and 45 per cent. chemical pulp respectively. The rubbings on the paper containing 100 per cent. chemical pulp showed more extensive damage than those on the other two papers. Large areas of colour were completely removed as the paper beneath was eaten. On the other two papers small bites were distributed over the surface of the colour, and were more extensive on the paper containing the greater amount of chemical pulp.

It seemed remarkable that this small difference in the amount of mechanical pulp in the paper should have such an effect on the attack on the surface, and further tests were made on papers containing mechanical pulp. These were obtained through the courtesy of the Forest Products Division of the Commonwealth Council for Scientific and Industrial Research and the Australian Paper Manufacturers and comprise:—

(A) 100 per cent. bleached sulphite pulp.
(B) 100 per cent. chemical pulp from Eucalyptus wood.
(C) 80 per cent. bleached sulphite—20 per cent. mechanical (6 per cent. clay and rosin).
(D) 75 per cent. unbleached sulphite—25 per cent. mechanical.
(E) 52 per cent. sulphite—48 per cent. mechanical. (6.4 per cent. ash.)
(F) 45 per cent. sulphite—55 per cent. mechanical. (11.4 per cent. ash.)
(G) 30 per cent. sulphite—70 per cent. mechanical. (Newsprint.)

The papers were dipped in methylene blue so that any slight surface attack could be detected as the more deeply stained fibres on the surface were removed. Comparison with uncoloured samples showed that the methylene blue did not affect the attack. During the first ten days, papers A and B containing 100 per cent. chemical pulp were readily eaten, and after 30 days papers C and D containing 20 and 25 per cent. mechanical pulp showed some attack; but the papers with more than 48 per cent. mechanical pulp were not attacked even after 90 days. In each case the papers were removed from the test as soon as the attack was seen.

As mentioned above, it had been noticed that the composition of the paper affected the extent of attack on the surface coating. This observation was confirmed by coating the papers A to G

with a palatable gum which was dyed crimson to facilitate observations. The gum was readily eaten off the papers of chemical pulp and the attack extended to the paper. But the gum on the papers of mechanical pulp was much less eaten, and even after 90 days very little attack occurred on the gum coating on paper F and the newsprint.

As no commercial papers containing between 25 per cent. and 45 per cent. mechanical pulp were available, sample papers were made from weighed quantities of mechanical and bleached sulphite pulp and the final composition of the papers was checked by counting the fibres under the microscope using the method described by Gaff, 1935. The papers thus prepared contained 64, 33, 30, and 23 per cent. mechanical pulp. Of these, the paper with 23 per cent. mechanical pulp was well eaten, the papers with 30 and 33 per cent. were slightly eaten, but no attack was made on the papers with 64 per cent. mechanical pulp even after four months.

It was concluded from these experiments that:—

1. Papers containing 100 per cent. chemical pulp—sulphite, bleached and unbleached—are readily eaten.
2. The presence of even 20 per cent. mechanical pulp greatly reduces the attack.
3. Papers containing 45 per cent. or more mechanical pulp are not damaged.

The Cause of the Unpalatability of Mechanical Pulp:—An attempt was made to find the cause of the unpalatability of the mechanical pulp. In the preparation of mechanical pulp, the wood, mainly spruce and hemlock, is rubbed into small fragments. In the preparation of chemical pulp the substances which impregnate the walls of the wood fibres are removed, and the cellulose itself is partly decomposed. Thus the fibres of the chemical pulp are different from those of the mechanical pulp, both in chemical composition and physical texture, and probably both these factors contribute in determining the palatability of the pulp. In the Kraft process the chemical action is not carried so far, and some of the unpalatable properties of the mechanical pulp still remain.

Very little is known about the chemical nature of the materials which impregnate the cellulose walls of a wood fibre, but various materials have been isolated from the mechanical pulp extracts, and an attempt was made to find the effect of these materials on the palatability of the pulp.

First the mechanical pulp was extracted successively with ether, alcohol, hot water and 5 per cent. sodium hydroxide. Other samples of the pulp were extracted separately with the above solvents and 3 per cent. sulphuric acid. "Bond" paper was soaked in these extracts for 24 hours and then subjected

to the attack of silverfish. It was found that all the papers were readily eaten except those impregnated with the ether extract, which delayed the attack for three months. The materials extracted were decomposed by exposing the impregnated paper to sunlight for two weeks. The extract was bright yellow. It could be decolourized by charcoal or barium sulphate, but the colourless extract did not render the paper unpalatable.

The effects of various chemicals associated with the resins and fats of wood were also tested by impregnating the Bond paper with solutions of the substances in carbon tetrachloride. Oleic and linoleic acids proved ineffective, but abietic acid prevented attack for one month. Samples of wood extracts, lariciresinol, sitosterol, matairesinol, and a benzene-alcohol extract of paper pulp resin were kindly supplied by Dr. R. D. Haworth of the University of Newcastle-on-Tyne. Three per cent. solutions in acetone were used. Both lariciresinol and matairesinol prevented the attack on paper: but both caused the paper to turn a light brown, and both made it slightly sticky.

It was thought that the physical texture of the mechanical pulp might contribute to its unpalatability, and an attempt was made to test this by preparing papers from the mechanical pulp after it had been extracted with water, acid, alcohol and ether, as in the above tests. Some difficulty was experienced in making paper from the mechanical pulp because it would not hold together, and it was hard to see if any attack occurred on the surface. Certainly the attack, if any, was very slight.

The state of the cellulose itself also affected the palatability of the paper. Spruce wood pulp is high in hemicelluloses which are readily degraded during the chemical pulping. Further, as prepared for the " Bond " paper, the pulp has a large percentage of fragmental fibres produced during the beating, and both factors probably contribute to the palatability of this type of paper. In contrast to this, the pulp for filter paper (which is not readily eaten) is prepared from rag cellulose low in hemicelluloses, and so treated that all the degraded celluloses are removed leaving only the resistant α-cellulose. Duplicating paper (d.c. 48, from Thomas Tait) which also is not readily eaten contains a high percentage of Esparto fibres. These fibres are low in hemicelluloses, and, since they are only lightly lignified the treatment is so mild that little degraded cellulose is produced. The pulp is beaten for only a short time. It would seem therefore that this pulp, too, is not easily digestible.

Even though the silverfish will eat and digest any kind of cellulose, particularly if it is made palatable by mixing, for example, starch paste with sawdust, or large amounts of chemical pulp with the mechanical pulp, it is understandable that the attack should be more pronounced on the celluloses which are the most easily digestible.

Deterrent Sprays:—Since it is not possible in practice to eliminate the attractive materials from the wallpaper, an attempt was made to find some deterrent which could be sprayed on the surface. The 69 substances selected for the tests were derivatives of phenol, cresol, and salicylic acid, and salts of barium, mercury, tin and antimony (see Appendix). Water, methylated spirits, and a petroleum fraction "White Spirits" were used as solvents with several concentrations of each substance. The protection to both wallpaper and "Bond" paper was tested.

The appearance of the attack on some of the wallpapers suggested that areas were left uncovered as the spray dried. The distribution of the spray was tested by the reaction of ferric chloride on papers sprayed with salicylic acid, and by spraying with methylene blue. It seemed that the spray covered the surface, but did not penetrate far, so that underlying unimpregnated colour and paper fibres were readily exposed. An attempt was made to reduce the surface tension of the alcohol and water solutions by the addition of cetyl alcohol, but the deterrent action of the sprays made in this way did not last longer than before.

Finally a 1 per cent. solution of tricresylphosphate in White Spirits, and a half saturated solution of Tartar emetic in water were selected. Both protected the surface for nine months. A small amount of damage occurred on the Tartar emetic sprayed paper, but the insects died. The insects made no attempt to eat the paper sprayed with tricresylphosphate. Apparently they detected its unpalatability without biting the surface.

Adhesives:—Twenty-four commercial adhesives were tested in thin layers spread on "Bond" paper. The pastes, gums, dextrin, casein, and cellulose adhesives were all readily eaten off the surface of the paper. The glues were less readily eaten, the attack occurring only on the edges. Only two adhesives, a gum and a glue, were not attacked, and it is probable that the preservative in these acted as the deterrent.

Tricresylphosphate and Tartar emetic were added to a starch paste and a gum. Attack on the paste was prevented by 4 per cent. of the tricresylphosphate, and 5 per cent. of the tartar emetic (both per cent. weight of flour). Attack on the gum was prevented by 1 per cent. Tartar emetic and 2.5 per cent. tricresylphosphate (by weight). With lower concentrations of the deterrents the paper was eaten, and at still lower concentrations the adhesive itself was eaten off the surface of the paper.

Artificial Silk:—Artificial silk is very readily eaten (pl. I, figs. 3 and 4), but treatment with certain materials for fire proofing and water proofing rendered the silk so unpalatable that it was eaten only by starved insects. When this treated silk was smeared with a palatable mixture of sweetened flour paste, the paste and the silk underneath were readily eaten, and the

attack extended to the surrounding strands. The tricresylphosphate spray rendered the untreated silk so unpalatable that, when soiled in the same way, the paste was eaten from between the strands of the material with very little damage to the strands themselves.

Poison Baits:—The taste sensitivity of the silverfish was important also in the preparation of poison baits. These baits were developed by the Division of Economic Entomology of the Commonwealth Council for Scientific and Industrial Research (Jr. C.S.I.R., 1939, p. 85).

5. Digestion and Absorption.

The Process of Digestion:—The digestive tract is simple (fig. 2). The large thin-walled crop extends to the third abdominal segment—more than half the length of the body. A pair of large salivary glands which lie around the anterior end of the crop, open on the hypopharynx, and may be the source of the small amount of fluid which moistens the food during chewing. The food is moved about slowly in the crop (peristalsis is not strong) and is further broken down by the teeth of the gizzard. It would seem that some chemical decomposition also takes place in the crop as the material which passes into the mid-intestine is very finely divided. There is no evidence that any secretion occurs in the crop and, possibly, digestive fluids pass forward from the mid-intestine.

The semi-fluid mass passes from the gizzard into the mid-intestine. In the anterior region of the mid-intestine, the material lies in the sacculi, but in the posterior region it is held within a well-marked peritrophic membrane. Presumably this membrane is secreted by all the cells of the mid-intestine, for no special secreting cells and "press" (Wigglesworth, 1929), could be seen in the stained sections.

The hind intestine is lengthened by an anterior, dorsal, loop before it joins the rectum. The epithelium of the hind intestine is deeply folded, and the walls of the rectum are thrown into six well-marked longitudinal folds, and two rows of papillae surround the anus. This increased surface of the proctodeum is presumably concerned with the extraction of water from the faeces which are nearly dry when extruded.

The rate of digestion of paper was observed. A starved insect was given access to the paper for two hours. Within twelve hours some of the paper had passed into the mid-intestine, and an examination after 48 hours showed that all the fibres in the crop had been completely destroyed. Residual material first appeared in the hind intestine 24 hours after feeding and faeces were passed until the fifth day. With more indigestible material, e.g., insect remains and wool, faecal pellets continued to be expelled at intervals for seventeen days.

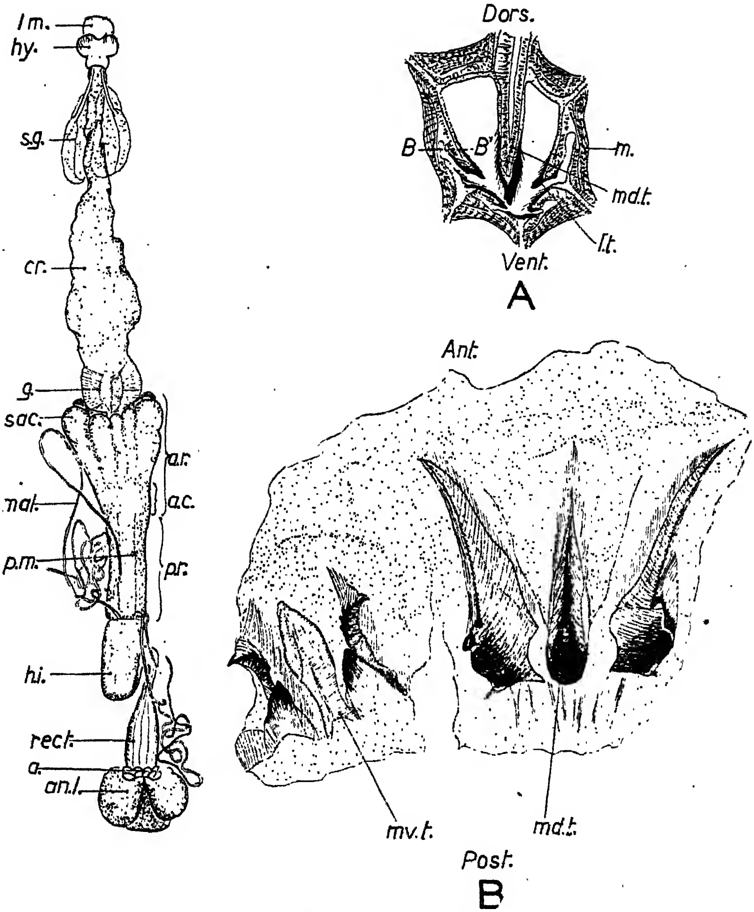

FIG. 2.—Alimentary canal and crop; *A*. Transverse section of crop and *B*. Crop opened on one side B-B[1]; *a*. anus; *an.l*. anal lobes; *cr*. crop; *g*. gizzard; *hy*. hypopharynx; *h.i*. hind intestine; *lm*. labrum; *l.t*. lateral tooth; *m*. muscle; *md.t*. mid dorsal tooth; and *mv.t*. mid ventral tooth of gizzard; *mal*. malpighian tubule; *a.r*. anterior region; *p.r*. posterior region and *a.c*. absorbing cells of mid intestine; *p.m*. peritrophic membrane; *rect*. rectum; *sac*. sacculi; *s.g*. salivary glands.

Cellulose Digesting Bacteria:—Insects feeding on cellulose usually depend on the lower organisms in their intestine to assist in the digestion of the cellulose, and it was found that cellulose digesting bacteria could be readily cultivated from the contents of the crops of silverfish.

Thirty ccs. of Winogradsky's medium (1929), after sterilization, were mixed with the expressed contents of one crop. A piece of filter paper was half immersed in the liquid, and kept at 24°C. for one week. The paper at the water level became

brownish, and below the water very gelatinous. When examined under the microscope the fibres had the "chewed" appearance typical of the action of these bacteria. There were many cocci and bacilli both on the surface and inside the fibre. The paper in the uninoculated salt medium was unchanged.

Fungal hyphae, which were frequently found growing in the crop also may aid in digestion.

The pH of the Alimentary Canal:—An attempt was made to measure the pH of the contents and cells of the alimentary canal by feeding the silverfish on paper dyed with indicators. Although conditions were not suitable for determining the depth of colour of the indicator, the change in colour could be seen, and, by using a range of indicators, the pH of the region determined. The indicators used were:—2, 4 dinitrophenol, phenol red, naphtholphthalein, tropoeolin 000, cresol red, brom-thymol-blue, brom-cresol-green, methyl red, para-nitrophenol, brom-cresol-purple, meta-nitrophenol, and thymol blue. The colour of the indicator was noted in a rapidly dissected insect. There was no disagreement in the results from any of the indicators.

The pH of the crop was always the same as that of the food. The pH of the anterior region of the mid-intestine was difficult to see, owing to the thick walls, the fluid nature of the contents, and the rapid entrance of food from the crop. It appeared to be between 4.8 and 5.4. The pH of the posterior region of the mid-intestine was between 6.4 and 7.0. The pH of the hind intestine was lower, between 2.6 and 3.8, possibly owing to acid excretory products.

Several of the indicators, viz., meta-nitrophenol, para-nitro-naphtholphthalein, tropoeolin 000, cresol red, and brom-cresol-green, were absorbed in the cells of the anterior part of the mid-intestine in apparently the acid form, but they no longer responded to pH changes.

Several of the indicators, viz., meta-nitrophenol, para-nitrophenol and methyl red, were found to be unsuitable because they were changed in the intestine and no longer indicated pH, or because their colour change was indefinite under these conditions.

The indicators were fed to the silverfish also on casein and sugar, and it was found that the nature of these foods did not affect the pH of the alimentary canal.

Redox Potential:—Using the same methods as above, the indicators, o-chlorophenol–indophenol, toluylene blue and methylene blue were fed to the insects.

Ortho-chlorophenol-indophenol was decolourized in all parts of the alimentary canal. Toluylene blue was present in the oxidized form in the crop and mid-intestine, where it could still be decolourized by sodium sulphite. Methylene blue was present throughout the alimentary canal in the oxidized form.

The Distribution of Certain Dyes:—These indicators and other dyes stained other parts of the body as well as the mid-intestine. When absorbed in these tissues the methylene blue could still be decolourized with hot sodium sulphite, but the toluylene blue could not be decolourized and no conclusions could be drawn about the Redox potential of these parts.

The methylene blue was absorbed by the mid-intestine, appearing in the cells of the anterior region within 24 hours, and in those of the posterior region on the fifth day. In each case the cells appeared to be filled with blue globules which were larger in the anterior region than in the posterior region of the mid-intestine. The crystals of excretory material in the faeces stained blue, and within four days the methylene blue appeared in the malpighian tubules located in indefinite patches of cells along their length. By the twelfth day the methylene blue coloured the immature eggs, the yellow cells of the ovarioles, and the edges of the fat bodies.

Sudan III was fed to the insects on ground wheat. Part was readily absorbed by the cells of the mid-intestine. Three days after feeding, red globules appeared in the cells of the malpighian tubules; the fat bodies were coloured a deep pink; the immature eggs, and the material inside the dilated portion of the vasa differentia were coloured pink; the accessory glands of the female were coloured red. In one female the eggs had passed into the calyx. The contents were coloured pink, but it is not known whether the dye penetrated the chorion, or whether the egg stained before this had formed. The colour persisted in the ovarioles for about twenty days, and even after 85 days the cells of the mid-intestine and the fluid in the crop still remained red, though, by this time, none of the other organs retained any Sudan III.

The appearance of the dyes absorbed in the mid-intestine was different in the cells of the posterior half from those in the anterior half. Two more regions in the anterior half (fig. 2) were distinguished by the appearance of the absorbed toluylene blue and Sudan III. These latter differences could not be correlated with any structural differences in the sections stained with Heidenhain's haematoxylin, and their particular function in digestion is not known.

A number of other red dyes were also tested in order that the form of the alimentary canal could be photographed through the semi-transparent chitin of the nymph. Magenta, carmine, and aniline red were all readily eaten, but were not absorbed in the mid-intestine, being merely concentrated in the faeces. Eosin and orange G. proved toxic.

IV. The Life History.

The first observations on the life history of the silverfish were made by J. W. Raff in 1933. The life cycle extends over several years. The nymphs develop with very little change in form. Sexual maturity is reached in $2\frac{1}{2}$ to 3 years and the adults continue to grow, moult, and lay eggs for at least three years longer.

1. The Egg.

Eggs are laid in lots of from two to twenty. In normal conditions they are pushed by the long ovipositor about 2 mm. into a crevice and so are rarely seen. Some have been found under the edge of a piece of pasted paper, and in a crack in a wooden drawer. They are oval and measure 1.15 × 0.83 mm. (average of 15). When first laid they are cream coloured and smooth, but after three days the chorion darkens to a yellow and shows shallow reticulated markings.

The young insect bursts the shell with a small ridge on the frons, the hatching organ (fig. 3). This is shed with the first exuviae. The crop pulsates vigorously during hatching. It is filled with air, although the mouth appears to be closed throughout the first instar. After about five minutes the insect wriggles

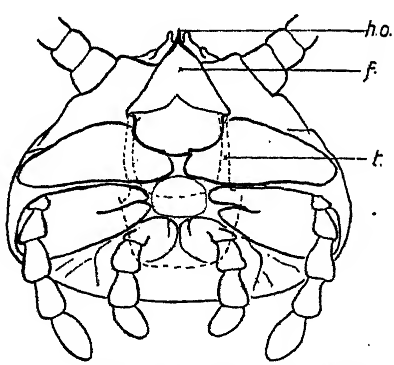

Fig. 3.—Head of 1st instar from ventral surface showing hatching organ and tentorium; *f.* frons; *h.o.* hatching organ; *t.* anterior arm of tentorium.

free of the shell. In captivity almost all of the eggs hatched, and there were very few deaths during the early instars. Other references to the hatching organs of *Lepisma saccharina* are included in the Bibliography (Heymons, van Emden, Wigglesworth).

2. The Early Instars.

The development of the first fourteen instars was followed. The length of the successive stadia showed considerable variation even at a constant temperature of 23°C. (Table I.). The distinctive characteristics of the successive instars were not easy to

define, for these resembled each other closely in all but the few features described later. The new instars were distinguished by their complete coat of scales which are tightly adherent during the first few days of the stadium. In general, growth results in a gradual increase in size, and in the elaboration of both the internal and the external structures present in the young insects. The feeding habits are the same. The cells of the mid-intestine are already differentiated as in the adult. The gizzard has the same form as in the adult though there are fewer serrations and hairs on the teeth. The malpighian tubules are relatively large until about the twelfth instar. The eyes have twelve ocelli as in the adult, but these are rather more rounded.

TABLE I.—DURATION OF EARLY STADIA AT 23°C.

Instar.	Number of Insects.	Average Length of Stadia Days.	Range Days.	Instar.	Number of Insects.	Average Length of Stadia Days.	Range Days.
1	40	3	3–4	8	16	37	24–46
2	14	11	6–15	9	17	41	25–64
3	20	13	10–15	10	9	39	27–57
4	4	17	16–19	11	6	39	24–51
5	10	23	16–35	12	2	39	33–46
6	16	25	16–37	13	2	43	40–47
7	18	31	19–46				

As the silverfish is not heavily chitinized, and the segments are easily stretched, measurements of the total length of the body were of little value. Instead, the measurement of certain organs which have well defined limits, and which do not change during the stadium, were compared. The following organs were selected (fig. 4) :—

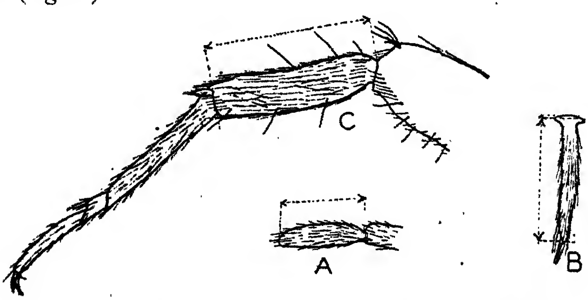

FIG. 4.—Parts used for comparative measurements of the early instars; *A*. Terminal segment of maxillary palp; *B*. Style; *C*. Anterior edge of metathoracic leg.

(*a*) The terminal segment of the maxillary palp.

(*b*) Styles.

(*c*) The anterior edge of the tibia of the metathoracic leg. The antennae and posterior appendages were also measured when these were complete.

One hundred insects were used. They were kept at 23°C. and five to ten individuals of each instar were killed and mounted in De Faure's fluid so that the measurements could be made.

Preliminary observations on the change in size of the selected organs during the stadium showed that no further change occurred after the second day. (The measurements were usually made about four days after ecdysis.) Since it was necessary to kill the insects to make the measurements, the increase in size of an individual could not be determined. The organs of both the right and left side were measured and these were found to be usually the same size. (Exp. error ± 0.003 mm.) When the measurements differed, the mean of the two was used. The individuals of any one instar varied considerably, but a consideration of all the information enabled the instar to be decided with some degree of certainty. The average measurements for each instar are shown in Table II. The lengths of the styles

Table II.—Average Measurements (mm.) for the Instars 1–14.

Instar.	Anterior edge of head to posterior tip of abdomen.	Terminal Segment Maxillary palp.	Anterior Edge Metathoracic Tibia.	Styles.		Antennae.	Cerci.	Appendix Dorsalis.
				Seg 9.	Seg. 8.			
1st ..	2.9	0.130	0.210	..	..	1.16	0.505	0.72
2nd ..	3.4	0.160	0.265	..	..	2.35	1.04	1.52
3rd ..	4.4	0.176	0.312	..	..	2.78	..	..
4th ..	4.8	0.184	0.360	0.107	..	3.3	1.87	2.75
5th ..	4.8	0.206	0.404	0.252	..	3.9	..	..
6th ..	4.9	0.232	0.462	0.338	..	4.0	..	..
7th ..	5.5	0.244	0.501	0.396	..	4.5	2.8	3.8
8th ..	5.7	0.264	0.566	0.470	..	5.3	3.1	..
9th ..	7.0	0.287	0.624	0.532	0.160	5.6	3.7	4.5
10th ..	7.2	0.294	0.678	0.617	0.210	6.1	3.9	5.4
11th ..	7.8	0.325	0.747	0.699	0.291	..	..	6.0
12th ..	8.0	0.356	0.833	0.745	0.451	7.9	5.6	6.0
13th ..	9.7	0.373	0.904	0.856	0.571	8.5	6.5	8.5
14th .	9.4	0.421	0.985	0.902	0.586	10.4	6.9	8.5
(Last Observed)								

for the two sexes have been averaged together; for, although in the mature insects the relative lengths in the two sexes is different, the ratio being 1 : 1.56 for the male and 1 : 1.46 for the female, no consistent difference was found in these early instars.

There are also characteristic changes which enable certain instars to be distinguished fairly easily. Among these may be mentioned the following:—

The first instar is a pale cream colour without hairs or scales. The appendages are soft and relatively short, and the anus appears to be closed.

The second instar is a darker cream. The chitin is firmer and the appendages are longer and can be freely vibrated by the insect. A few bristles mark the position of most of the "brushes" of the adult. [The number of bristles increases in

the following instars and the bristle pattern may be found to be characteristic for each instar (cf. Buxton, 1938). The articulations are distinct even after the bristles have been lost. The patterns were however not studied in detail as it was realized that the size of the selected organs seemed to give an easier indication of an instar.]

The third instar is very active. It is dark cream in colour with purple tinting on the edges of the thoracic terga and the anal lobes. This colour persists in the succeeding instars.

The first three instars can be distinguished also by the tarsal segments. Each leg of the newly hatched insect has two tarsal segments. In the next instar, however, a septum develops on the second tarsal segment of the third leg, and in the third instar all the tarsi are three-segmented as in the adult.

In the fourth instar the scales are present. In this instar also the styles first appear, one pair being developed on the ninth sternum. They are "stubby" with many transverse "wrinkles." (The second pair of styles, which develops on the eighth sternum, does not appear until the ninth instar in the male and the eleventh instar in the female.)

It is interesting to note that the development during the first four instars resembles that of *Thermobia domestica* as described by Adams (1933).

In the fifth, sixth and seventh instars no particular distinguishing characters could be recognized.

In the eighth instar the genitalia first appear (fig. 5). They develop as two small lobes on the intersegmental membrane at the base of the cleft in the ninth sternum. This cleft first appears on the second instar, and becomes more and more marked until,

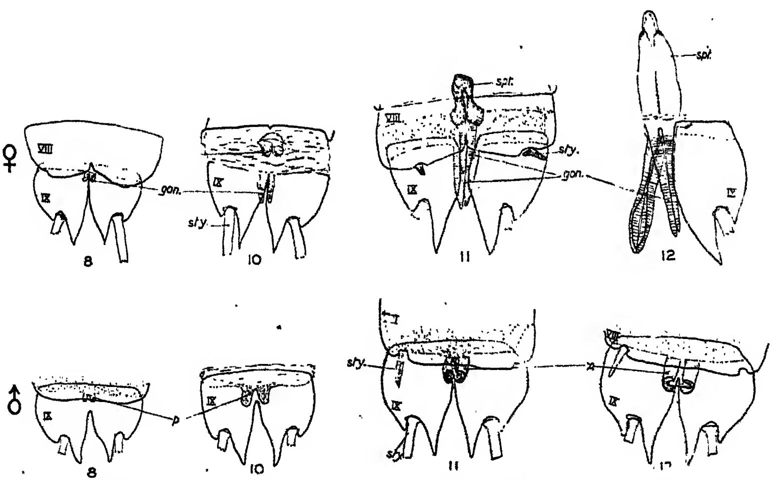

FIG. 5.—The genitalia of the young nymphs—ventral view; female 8th, 10th, 11th, and 12th instars; male 8th, 10th, 11th, and 13th instars; *gon.* gonopophyses; *p.* penis; *spt.* spermatheca; *sty.* styles.

in the eighth instar, the two sexes can be distinguished by its shape. The two sexes can be further distinguished by the small cleft in the eighth sternum of the female, which also develops in the early instars and extends deeper in the successive instars until this sternum, too, is completely divided.

In the males these two lobes remain short until by the eleventh instar the shape of the penis can be distinguished. By this stage too the internal organs have formed. The reproductive organs of the adult male are shown in fig. 6A. In the nymphs the various parts can be distinguished. There are seven large testicles: the vasa deferentia are short, thin-walled, and slightly dilated at the distal end, and the two fuse immediately anterior to the penis. In the next instar they lengthen and form two loops between the two nerves of the cerci. In the thirteenth instar the vesiculae seminales form, and the rolled edges of the penis fuse ventrally so that this now has the same form as in the adult.

In the female the lobes elongate and in the tenth instar a second pair develops from the membrane between the eighth and ninth segments. In the eleventh instar the posterior lobes

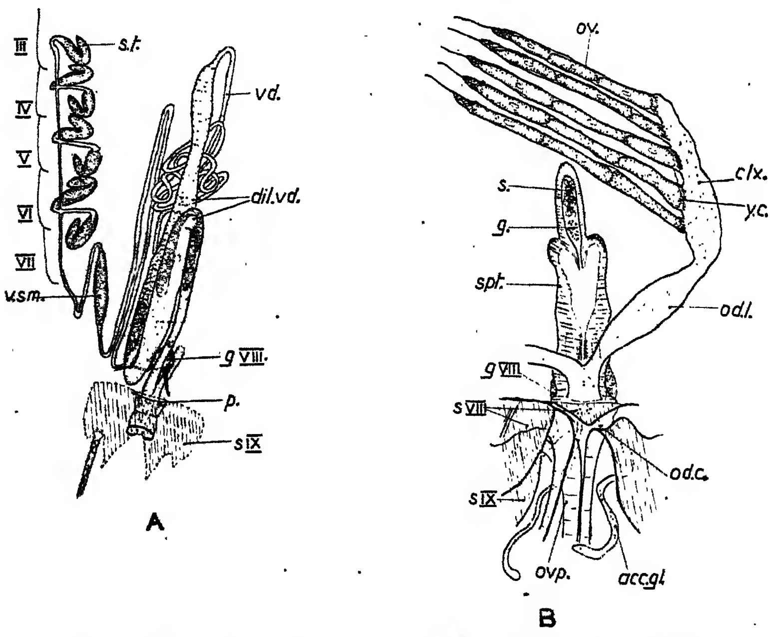

FIG. 6.—Reproductive organs of adult male *A.* and female *B.* (ventral view).
MALE:—*dil.vd.* dilated part of vas deferens; *gVIII* 8th ganglion; *p.* penis; *sIX* 9th sternum; *s.t.* sperm tube; *v.sm.* vesicula seminalis.
FEMALE:—*acc.gl.* accessory glands; *clx.* calyx; *gVIII* 8th ganglion; *od.c.* oviductus communis; *od.l.* oviductus lateralis; *ov.* ovariole; *ovp.* ovipositor; *s.* sperm, and *g.* granulated material in anterior prolongation of spermatheca, *spt.*; *t.f.* terminal filament; *y.c.* yellow cells.

elongate to within about 0.14 mm. of the points of the sternum, and the anterior pair extends ventrally to the base of the cleft in the ninth sternum. In the next instar the anterior pair are only a little shorter than the posterior pair, which now extend to within 0.08 mm. of the points of the sternum. In the thirteenth instar the two dorsal (posterior) lobes fuse and interlock with the two ventral (anterior) lobes as in the adult and the complete ovipositor projects about 1.2 mm. beyond the sternum.

At the same time the spermatheca develops. It appears first in the tenth instar as a short lobe directed anteriorly from the gonopophyses. In the twelfth instar it is already 0.6 mm. long and though the walls are still thin and undifferentiated, the two side sacs and the central neck are indicated (fig. 5). In the next instar the spermatheca has developed further and though it is still soft, the anterior prolongation, the neck region, and the two lateral pouches have well marked walls.

The internal reproductive organs have also formed by the thirteenth instar although the accessory glands and the "yellow" glands are not yet pigmented. The ovarioles still contain many small cells, the ova being not yet differentiated. The form of the organs in the adult female is shown in fig. 6B.

The detailed examination of the instars was not continued further than the fourteenth instar, as a preliminary examination showed that later development was concerned only with a very gradual increase in size.

In view of the extensive studies of growth rates which other workers have made, it is interesting to analyse the measurements of the instars of the silverfish in the same way.

The percentage increase in the average dimensions of the organs in the successive instars is shown in Table III. and it will be seen that this percentage increase is fairly constant, except during the first few instars. Apparently at its first appearance the organ is not as fully developed as is consistent with the later growth increments.

Table III.—Relative Increase in Length of Palps, Tibiae, and Styles for the First 14 Instars.

Instars.	Percentage Increase in Length.		
	5th Segment Maxillary Palp.	Metathoracic Tibia.	Styles of 9th Sternum.
1–2	123	126	..
2–3	110	118	..
3–4	105	115	..
4–5	112	112	235
5–6	113	114	135
6–7	105	108	114
7–8	108	113	117
8–9	109	110	119
9–10	110	109	113
10–11	110	110	116
11–12	105	111	113
12–13	113	108	106
13–14	..	109	115

Measurements were also made of the adult insects, comparing the organs of one side which were removed with those of the other side after the ecdysis. Although the adult insects increase in size over a period of several years, no regular increase in the size of these organs was observed, and in some cases they were the same size or smaller than those of the other side in the previous instar. Part of this discrepancy was probably due to regeneration.

The growth co-efficient (Huxley, 1932) of an organ is generally found by measuring its increase relative to that of the body when expressed by the formula:—

$$y = bx^{a}$$

where y is the size of the body; x is the size of the organ; b is a constant and a is the growth co-efficient.

i.e., the graph of log. (size of body) against log. (size of organ) is a straight line of slope.

Since the growth co-efficients of any two organs can be represented in this way, the relative growth of the two organs must follow the same type of curve. The relative growth of the palp and styles was compared with that of the metathoracic tibia, and the value of a for the palp was found to be 0.8, and for the styles 1.48. The same growth rates seem to be maintained until maturity. In fig. 7 the measurements of the individuals of three instars are shown. There is an almost continuous gradation in size between the instars, which is only to be expected when so many ecdyses are concerned in the growth of a nymph so similar in form to the adult.

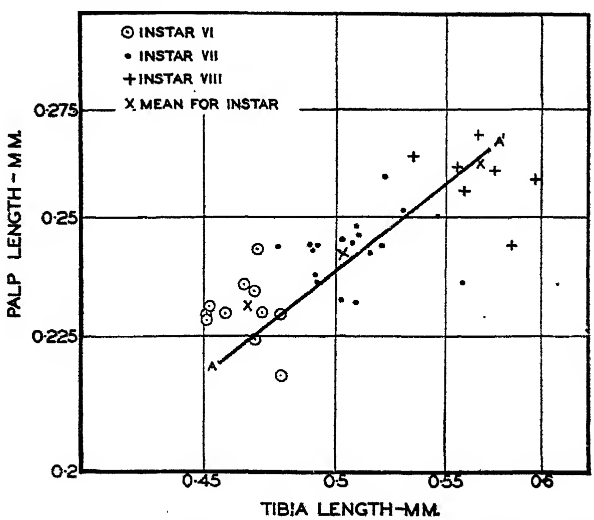

FIG. 7.—Variation in length of palp with length of tibia for three successive instars. Plotted on log-log scale. The slope of A-A¹ is the growth co-efficient of first 14 instars.

3. The Adult.

Ecdysis and Feeding:—Ecdysis continues after the silverfish reach sexual maturity. The relation of ecdysis to feeding was followed by observing the daily feeding of twenty individuals maintained at 24°C. In every case the insects did not feed during the last third of the stadium. During the first portion of the stadium they fed actively, although usually, there was a short period of one to three days before feeding began. These periods of no feeding presumably allow time for the old chitinous lining of the alimentary canal to be shed and the new one formed. (See p. 46.)

The insects which are found at night crawling about the floors and walls are usally in this feeding period of the early portion of the stadium. A number of these insects were collected and the rate of moulting watched; for example, one group of eighty-two insects collected on March 8th, 1937, started to moult ten days after capture (fig. 8). This continued for 60 days, when the last insect moulted. In another group of 30 insects caught on the 27th July, 1937, the same thing was observed; but, in this group, the last ecdysis did not occur until more than 100 days after capture. About 80 days after capture (October) the numbers of insects moulting greatly increased, probably because of the increasing room temperatures.

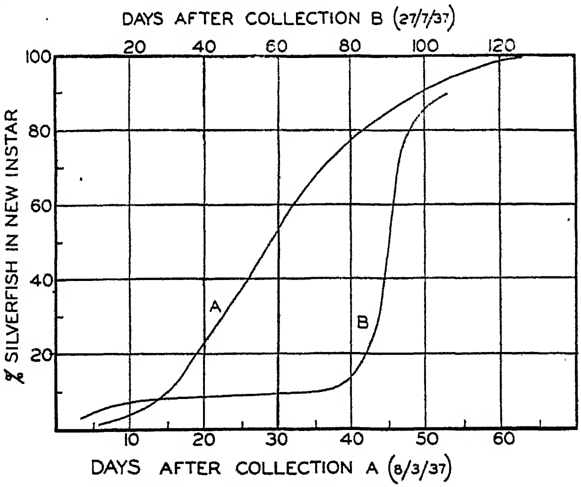

Fig. 8.—Length of time after capture before ecdysis occurred. Note the effect of increasing room temperatures in the rapid ecdysis in October of the insects collected 27.7.37. (Graph B.) The time scales of the two graphs are different.

Ecdysis:—The approach of ecdysis can be seen by the darkening of the new scales beneath the cream chitin of the old cuticula, from which, by the end of the stadium, most of the scales have been rubbed. This darkening increases during the last two to

three days of the stadium. When the new cuticula is completely formed, the insect starts to work the abdomen gradually forward until free of the last two segments of the old cuticula. Ecdysis then proceeds more rapidly. The abdomen expands and contracts; a deep furrow develops in the mid-dorsal line of the thorax and along the epicranial suture; the head is bent ventrally with the antennae and legs directed posteriorly, and the thorax is "hunched" until the furrows split. The head is dragged free, followed by the antennae and legs, and the cuticula is worked off the end of the abdomen. This part of the ecdysis is completed in ten to fifteen minutes.

The linings of the crop, gizzard, hind intestine and spermatheca are cast at the same time. Dissections showed that even before the new cuticula had formed, the lining of the crop and hind intestine were free in the lumen of the alimentary canal. The crop lining was broken off at the pharynx and with the lining of the gizzard passed back with the faeces.

It may be noted that in most insects the crop lining is cast through the mouth. In the case of the silverfish, the crop remains attached to the gizzard, and casting through the mouth is prevented by the arrangement of the large teeth of the gizzard. These can, however, be pushed backwards through a narrow opening for they fold into one another.

Under experimental conditions it was noticed that the silverfish were very slow-moving during the last days of the stadium. At this time, and during ecdysis they were readily attacked by other silverfish (particularly if the diet was not adequate). The exuviae were often eaten. Under unfavourable conditions it often happened that the insects died when the first split developed, or else they failed to draw the thorax out of the cuticle which then broke at the anterior end of the abdomen.

Mating and Egg Laying:—The cycle of growth and ecdysis influences mating and egg laying. The two sexes occur in about equal numbers. The spermatophore is probably formed at the time of copulation. It consists of a loose bag (1.5 mm. diameter) enclosing a coiled tube which ends on a long neck and pointed cap. It is presumably formed by the vasa deferentia of both sides (fig. 6) for the vas deferens of one side never seemed to contain fewer sperm or less gelatinous material, as might have been expected if the spermatophore were formed by one side only.

The neck of the spermatophore is pushed through the vagina into the body of the spermatheca, the tip fitting into the base of the anterior prolongation. The sperm are passed forward into the prolongation, preceded by a mass of finely granulated material. The female then eats the spermatophore from the base of the ovipositor, and in less than fifteen minutes there is no longer external evidence that mating has occurred. Copulation has not been observed but it is difficult to see how the long neck

of the spermatophore could get into the vagina of the female unless transferred directly by the male. (Compare Sweetman, 1938).

The chitinous lining of the spermatheca is always thick in the fertilized females; but whether this is merely due to age, or whether it is due to the stimulation of mating is not known. The posterior part of the prolongation of the spermatheca is closely constricted and must relax to permit movement of the sperm. There is also another constriction at the base of the body of the spermatheca. This is distended by the entrance of the spermatophore.

Mating probably occurs after each ecdysis as the contents of the spermatheca are lost when its lining is cast. On several occasions it was noticed that the females bearing spermatophores were in the early part of their stadium. The stage of development of the eggs at mating does not seem to be important, for sperm were found in the spermatheca of females with either medium sized or large eggs, and in other females containing large eggs no sperm were found. Females isolated from males continued to lay fertile eggs until ecdysis. The eggs laid after this soon turned yellow and shrivelled. Usually two or three batches were laid after the separation and then the females continued to live for two years apparently quite normally, but laid no more eggs.

The stimulus for the formation of the spermatophore is not known, but it is not a seasonal process. Dissections of males throughout the year revealed that the vesiculae seminales always contained active sperm, and on one occasion—in June, 1938—a number of insects were transferred from room temperature (about 10°C.) to 24°C. and several spermatophores were formed overnight. Apparently the males were in a condition to function as soon as the temperatures increased.

The length of time the eggs take to develop in the ovarioles is not known, but the development is not seasonal. Both large and small eggs were found in the ovarioles in both winter and summer. The lower two or three eggs apparently mature at the same rate in each of the ovarioles, and development proceeds at the same rate in the two ovaries.

An attempt was made to watch the rate of egg laying of isolated pairs of adult insects and of groups of three or four insects—220 in all—but very few eggs were laid under these conditions and the males were frequently eaten by the females. Dissections showed that the females contained nearly mature eggs but there was no evidence that copulation had occurred. This is in accord with the observations of Sweetman (1938), who found that several males were necessary to stimulate the act of copulation.

Another series of observations was made on 124 females and 96 males held in groups of 10 to 40 insects. These were watched

from February, 1937, to June, 1939, and during this time 4,573 eggs were laid (during this period 34 females and 24 males died or were removed). The average number of eggs laid per year by each female was 56. This occurred mainly in the summer, between the end of November and the middle of March, but a comparison of the rate of egg laying over the whole period showed some relation to room temperatures; for example, in 1938, egg laying continued until July, during which time the temperature was higher than in 1937. Again in March, 1939, higher temperatures resulted in greater egg laying.

V. The Effects of Temperature and Humidity.

1. Temperature.

Length of Stadium:—The effect of temperature on the length of the adult stadia, on the nymphs, and on the eggs was tested. The apparatus used was the multiple temperature incubator developed by Andrewartha (1935) for Thrips, and provided ten different temperatures. The temperatures of the insect containers were affected by outside temperatures to some extent, and it was necessary to calculate from the daily readings the mean temperatures for any period under consideration. The insects were provided with the standard diet (p. 36) and the humidity in each container was controlled by a 4 per cent. solution of sulphuric acid. This kept a relative humidity of about 96 per cent. and prevented the growth of moulds which became troublesome at higher humidities. Other experiments showed that the insects were not affected as long as the relative humidity was above 50 per cent.

In the final tests 39 insects were used and the average temperature was calculated for the period of each instar. These temperatures were then grouped into intervals of 1°C. and the mean length of the stadium for the temperature interval was calculated. Although the insects used were of about the same size there was considerable variation in the lengths of stadia (Table IV.). However, the average lengths of the stadia showed clearly the increasing rate of growth at temperatures above 16°C. The greater activity above 20°C. was also evident from the rapidity with which the food was consumed.

Table IV.—Average Length of Adult Stadia at Various Temperatures.

Temperature °C.	Average Length Stadium.	Range.	Number of Insects.	Temperature °C.	Average Length Stadium.	Range.	Number of Insects.
	Days.	Days.			Days.	Days.	
29	15	..	2	22	43	30–58	4
28	17	20–15	2	21	46	38–65	6
27	30	13–44	10	20	67	49–106	11
26	40	35–46	2	18	59	50–68	2
25	39	24–50	8	16	129	121–142	4
24	51	36–79	3	15	165	100–239	4
23	37	21–46	6	14	220	106–263	4

The eggs and young nymphs were also subjected to a range of temperatures (Table V.). The individual rates of development were uniform for the egg and the first two instars.

TABLE V.—AVERAGE LENGTH OF HATCHING PERIOD AND 1ST STADIUM AT VARIOUS TEMPERATURES.

Temperature °C.	Period of Hatching.	Length of First Stadium.
	Days.	Days.
29·5	20	5
25·3	27	5
25·0	30	5
24·0	34	5
23·0	46	7
21·0	49	9

At temperatures below 13°C. the insects became torpid, and at 11°C. ecdysis stopped even if the cuticula had been partly shed. However, the process was completed when, a week later, the insects were put in a temperature of 24°C. Adult insects survived several months at 1°C. but second instar nymphs were killed in two days by the low temperature and at 11°C. survived for only twenty-five days. At 12°C. the length of life increased to seventy days.

Length of the Life Cycle:—In Melbourne, the life cycle extends over several years. Owing to some difficulty during the first year in providing a supply of food adequate for growth, insects have not yet been reared from egg to maturity. However, the total length of the life cycle can be estimated from observations of different periods. For example, in November, 1937, thirteen nymphs 4 to 10 mm. long were collected in the laboratory. These had probably developed from eggs laid the previous summer. By November, 1938, they had grown 10 to 12½ mm. and some laid eggs during the first week of December, 1938.

Under the conditions maintained for the stock insects (24°C.), eggs hatched in 34 days, the nymphs reached the thirteenth instar, 9½ mm. in eleven months, and would probably reach sexual maturity in eighteen months. At this temperature egg laying continued throughout the year.

It is interesting to compare these conditions with those maintained for *Thermobia domestica* (Sweetman, 1938).

Activity and Distribution:—These results obtained under controlled conditions may be compared with observations of the insect's normal activity. It is assumed that the mean air temperatures give a measure of the conditions obtaining in the insects' microclimate.

The prevalence of silverfish in the capital cities as judged from the reports of residents, pest destroying firms, and the Government Entomologists, can be related to the length of the period the temperatures are above 16°C., the limiting temperature

for active feeding and growing. It is only in those places which have long periods of temperature higher than 16°C. that the silverfish can increase to pest numbers. In a brick or stone house an indoor temperature of 16°C. normally corresponds to an outside temperature of about 55°F. (data received from the Commonwealth Meteorological Bureau, Melbourne). For example, the average daily temperatures were above this limit in Hobart for six and a half months, and Brisbane for the whole year. Very high temperatures do not limit the distribution of the silverfish in Australia, for air temperatures do not persist long enough above 30°C. to cause death.

The activity of the silverfish during the year in Melbourne can be related to the air temperature. During the winter months the metabolism is slow. Digestion proceeds slowly and observations on the stock insects showed that even some days after feeding, the crops still held many large fragments of digestible material. Since the need for food is reduced, the silverfish are seldom to be found at night on the walls and floors. For example, 25 weekly collections at 10 p.m. were made in one building during the period May to November, 1937. The average winter catch was fifteen, but during October, the number caught increased to 80. In all, 770 large insects were collected during this period.

These figures give an indication of the number of silverfish in a building which was not considered to be very badly infested. An occasional spraying was the only control used. Evidently

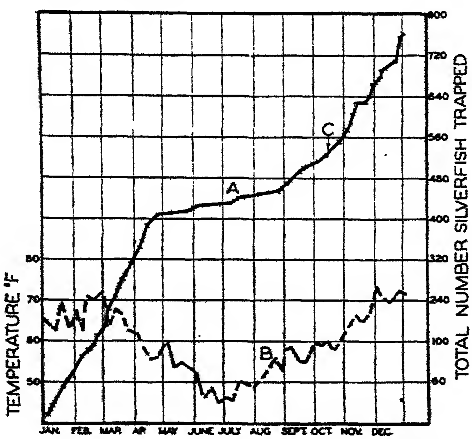

FIG. 9.—Influence of temperature on activity of silverfish. A. Progressive total of silverfish trapped in the sinks in one laboratory during 1937. The sinks were cleared each day. From October (point C) collections in other places also greatly increased. B. Mean weekly temperatures.

not all the insects are ranging on the walls and floors at the same time; for after an exhaustive search on four successive nights in October the same number of insects were caught on each occasion.

The number of insects accidently trapped in the sinks in one laboratory showed this same increase as the weather became warmer (fig. 9). Daily counts were made during 1936 and 1937, and, in both years, the numbers trapped increased greatly after October, when the mean weekly temperatures increased from 12.8° to 15.9°C.

High Temperatures:—The increased activity at higher temperatures continues to about 24°C.; but, temperatures higher than this are fatal, death occurring after a period which decreases from several months at 26°C. to one hour at about 41°C. (Table VI.). The effect of high temperature on other species of insect has been studied by many other workers (e.g., Buxton, 1931, Mellanby, 1932) with particular reference to the effect of moist and dry air, and to the possibility of some regulation of body temperature by the insect, at least, for short periods.

TABLE VI.—MINIMUM PERIOD OF EXPOSURE AT HIGH TEMPERATURES.

Temperature °C.	Period of Survival.	Number of Insects.
41·5	1 hour	9
40·0	15 hours	9
33·6	6 days	1
33·1	9½ "	4
32·6	9 "	6
31·3	24 "	2
31·0	16 "	2
30·1	8 "	7
29·5	21 "	5
29·0	11 "	2
26·0	4 months	10

These results were obtained in the multiple temperature incubator during the tests on maximum lethal temperatures.

The tests on silverfish were carried out by placing the insects in a test tube (2 in. x ¼ in.) suspended in a Florence flask in which humidities of 5 per cent. and 85 per cent. were maintained by solutions of sulphuric acid. The introduction of the silverfish through a tapering glass tube lowered the temperature of the flask, which required 30 minutes to return to that of the water bath in which it was immersed. The bath temperature was maintained to within ± 0.02°C. and a correction of 0.25°C. was applied, when necessary, to allow for the initial temperature drop. About 250 insects were used. After preliminary tests, 24 groups of nine insects each were used to determine the lethal temperatures for exposures of one hour and fifteen hours respectively.

In addition sixteen tests were made with periods other than one hour and fifteen hours.

For exposures of one hour, the highest temperature at which all the insects survived was 41.5°C. At higher temperatures an increasingly greater percentage of the insects died; but the mortality was lower in the dry air (fig. 10). Similarly for exposures of fifteen hours, the highest temperature at which all the insects survived was 38.8°C. Presumably, even during the short exposure of one hour, the body temperature of the insect was reduced by evaporation of the body fluids, though this point was not checked by measuring the weight lost by the insects during the test. After exposures of fourteen hours the effect of evaporation was still appreciable, but, presumably, in still longer exposures, this loss of water would be so great that the lethal temperature would be lower in dry air owing to the desiccation of the insects.

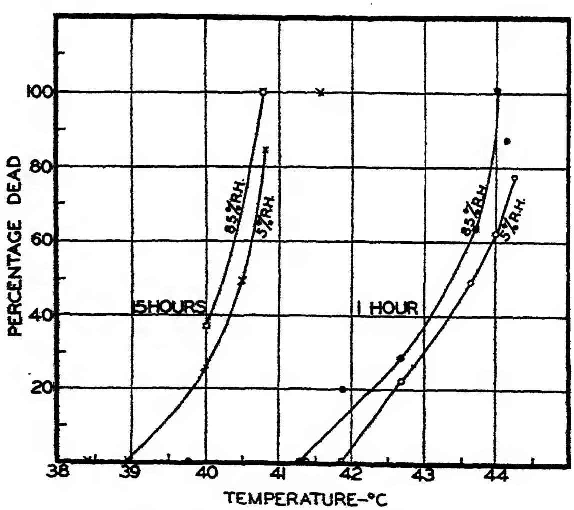

FIG. 10.—Lethal Temperatures for Exposures of one and fifteen hours in air of 85 per cent. and 5 per cent. Relative Humidity.

The variation in the reaction of the individual silverfish to the high temperatures is in accordance with that found in other insects. In the case of the silverfish, the variation was about the same in the two series of experiments, and was not greater in dry air as Buxton (1931) had found with *Rhodnius*.

In the third series of experiments, exposures of various periods were used, and those which caused the death of all the insects at the various temperatures (about five insects being used for each test) have been summarized in Table VII.

TABLE VII.—MAXIMUM PERIOD OF SURVIVAL OF ADULTS AT HIGH TEMPERATURES.

Temperature °C.	Fatal Period.
45·0	30 mins.
44·0	40–45 „
43·8	60 „
42·4	75 „
41·5	15 hours
39·5	40 „
38·0	72 „

After the silverfish had been exposed to high temperatures for fifteen hours or more, there was no difficulty in determining which were dead; but after a short exposure many became merely torpid. Some died but others recovered during the next 24 hours (and behaved normally at subsequent ecdyses). To take these insects into account the percentage dead at each temperature was calculated from the number dead 24 hours after the end of the test.

During exposure to high temperatures the silverfish moved about very rapidly. As soon as they were lifted out of the thermostat to cool, they became torpid, but again moved about actively when put back into the high temperature enclosure. This could be repeated several times. Finally, after 24 hours at room temperature, some of the torpid insects recovered. This behaviour is interesting in view of the possible causes of the lethal effects of high temperature which Mellanby has suggested. The only visible effect of the high temperatures was associated with the fats. The large fat bodies on the dorsal wall of the abdomen became so clear in the dead insects that the internal organs could be seen through the thin chitin. This "clearing" did not occur in the insects which merely became torpid, or in the insects killed by exposures of fifteen hours and longer.

The fact that the lethal temperatures were higher in dry than in moist seemed to indicate that the insects had some control over their body temperature, and an attempt was made to measure their rate of heating after they had been transferred to a higher temperature.

The method used was that generally adopted, i.e., the piercing thermocouple (Robinson, 1928ii); but a consideration of results showed that the silverfish was so small that the temperature of the couple was determined by conduction along the wires rather than by the temperature of the insect itself. It was concluded that only in an insect above a minimum size (depending on the conductivity of the tissues), would the thermocouple be at the same temperature as the insect.

A still more serious drawback to the method was the unavoidable injury to the silverfish. Although the silverfish could live for longer than one week while impaled on the junction, provided the crop had not been pierced, they were susceptible to high

temperatures and died after an exposure of one hour at 30°C. It was therefore not possible to test temperatures so high that any control of the body temperature by the insect itself could be expected to operate.

For the calculation involved in determining the rate of heating it was desired to know the specific heat of the insect. A calorimetric determination was attempted but the rise in temperature, which continued for one hour, was too great to have been derived solely from the heat of the insects, and it seemed probable that it was partly due to the heat of wetting.

The high value for the Specific Heat (1.4) obtained from the figures of Bodenheimer and Schmidt (1931) may be due to the inclusion of this "heat of wetting" in the total rise in temperature. No indication of the rate of temperature rise was given.

2. The Effect of Humidity.

The silverfish takes no liquid but must obtain its water from that absorbed by the food, and from that produced by the oxidation of foodstuffs. There is no excessive loss from the alimentary canal because water is absorbed in the hind intestine and rectum and the faeces are dry when extruded; but there is a continual loss from the tracheal system. The tracheae open at ten spiracles (fig. 11A), which have no closing mechanism, but are protected to some extent by the folds of the intersegmental membranes on which they are situated (fig. 11B). This simple tracheal system and the thin cuticle make the silverfish particularly susceptible to dry conditions. The effect of a range of humidities was studied and an attempt was made to understand the water relations of the tissues, when death occurred from drying. For most of the tests, adult, early stadium insects were used.

Water Content:—The water content of normal silverfish was determined by—

(*a*) drying at 103°C.;

(*b*) ether extraction of fat and water from the fresh insects.

The average water content of 165 insects was 72.4 per cent. The agreement of the results from the two methods showed that drying at 103°C. caused no appreciable decomposition of the tissues although the insects became brown during the process.

The individual determinations varied between 70.5 per cent. and 82 per cent. water. Variations of this order have been found in other insects. In the silverfish this variation could not be correlated with the moisture content of the food (as Robinson, 1928, had found in the grain weevils) although the food varied from paper (7–8 per cent. water) to a mixed diet containing some fresh plant tissue.

The relationship between the water content and the body weight can be shown by curves on a log/log scale. The "k" value for the silverfish 0.96 compares with the values for both the mealworm 0.975, and the wax moth 0.96 (Huxley, 1932) and shows that there is no relative change in the water content with body weight.

Effect of Dry Air:—The insects survived only short periods in air over calcium chloride. The average length of life of 35 insects was thirteen days; but there was considerable variation, the extreme limits being three days and 26 days.

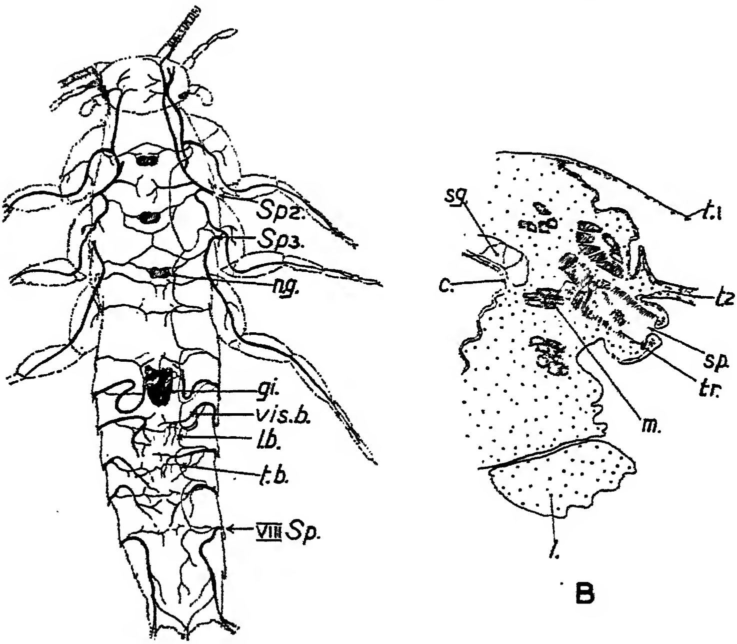

FIG. 11. TRACHEAL SYSTEM.—A. Dorsal View:—The dorsal system has been removed from the left side; *n.g.* nerve ganglion; *gi.* gizzard; *l.b.* lateral branch; *t.b.* transverse branch; *vis.b.* visceral branch. Sp_2, Sp_3, *VIIISp.* Spiracles of meso and meta thoracic segments and 8th abdominal segment.
B. Opening of 1st trachea:—Drawn from two successive sections 7μ. thick × 245; *l.* leg; *m.* muscle; *t1.t2.* terga I and II; *tr.* trachea; *sp.* spiracle; *s.g.* salivary gland; *c.* crop.

The rate of loss of water was determined from daily weighings of eighteen silverfish held at 24°C. Each insect was held in a small tube ¼ in. x ½ in. Nine were fed and nine starved. Two of each lot were kept under stock conditions as controls. These and

the one survivor were killed at the end of the test of 24 days, and the dry weight of all the insects determined. The total weight of the faeces was 0.15–0.6 mg., and was included in the weight of the insects at each measurement.

The individual rates of loss showed considerable variation but there was no significant difference between the fed and starved groups. The metabolic losses are small under these confined conditions, and as Gunn (1933) has shown, the loss of weight may be taken as a measure of the loss of water. The silverfish died after losing 20 per cent. to 75 per cent. of their weight. The average loss per day was 4.6 per cent.

The period of survival could not be correlated either with the rate of loss of weight, with the percentage of water lost until death, or with the water content of the body at death. For this latter figure the whole weight of the body was used, as the weight of the chitin is relatively small. No attempt was made to consider the water content of special tissues as Mellanby has suggested (1937).

The rate of loss of weight gradually decreased towards the end of the period, but it was usually the same five days before and after death, i.e., death was not followed by a suddenly increased loss of water. Even in insects still more susceptible to drying, e.g., *Phlebotomus* larvae, Theodor (1936), the rate of loss of water did not change at death.

Comparison of the Loss from Insects at Different Times in the Stadia:—The loss of water from insects late in the stadium was compared with that from insects early in the stadium. The insects were starved throughout the tests. Although during the first three and a half days the rates of loss of weight of the two groups was the same, over the whole period the late stadium insects lost water more rapidly than those early in the stadium. Their total loss until death was 66 per cent. compared with 57 per cent. for the early stadium, and the water content of the tissues at death was lower, 53 per cent. compared with 62 per cent. for the early stadium. (A determination of other groups of insects from stock showed a water content of 74.1 per cent. for the late stadium compared with 73.2 per cent. for the early stadium.) The late stadium insects also survived for a shorter period, the mean length of life for the group being 12.4 days compared with 16.3 days for the early stadium insects.

The slower rate of loss from the early stadia was probably due to the added protection of the layer of scales which are rubbed off the thin cuticle later in the stadium.

Loss of Water at Ecdysis:—Ecdysis is accompanied by changes in weight which are probably due to changes in the water content of the body. Even in moist air the insects lost about 8 per cent.

of their body weight during the seven days preceding ecdysis. This loss continued during the day after ecdysis and then the weight slowly increased.

The insects are most susceptible to dry conditions during the period of ecdysis, and after about four days' exposure they were not able to complete the moult. Death occurred usually after the old cuticle had split along the thorax.

Effect of Various Humidities:—The various humidities were maintained in Mason jars by sulphuric acid solutions of the required concentration. The insects were held in small tubes suspended in the jars, and paper and casein were provided. The tests were made at room temperatures.

The critical humidity seems to be about 55 per cent. There was some evidence that the length of life decreased at very low humidities (Table VIII.), which evidence is supported by the fact

TABLE VIII.—LENGTH OF LIFE AT VARIOUS HUMIDITIES.

Relative Humidity.	Number of Insects.	Period of Survival.	Range.
%		Days.	Days.
0–19	13	12	5–26
26–45	52	15	6–40
50–52	49	28	> 70
55	8	> 146	

that the rate of loss of weight was greater at the lower humidities (fig. 12, Table IX.). There was also some evidence that the length of life was shorter at higher temperatures for any given relative humidity.

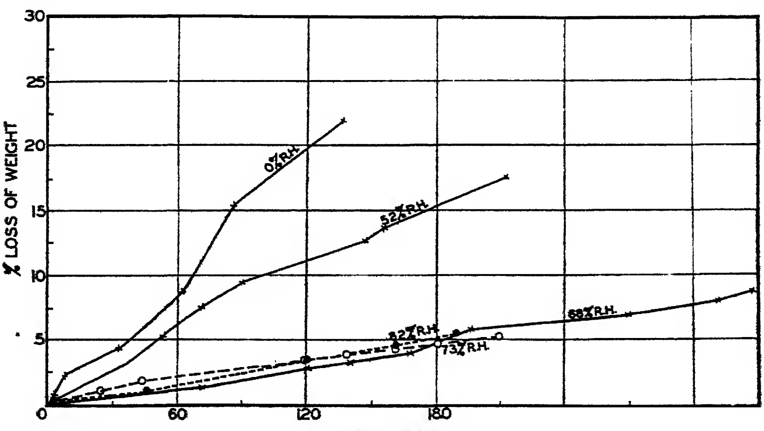

FIG. 12.—Rate of Decrease of Weight of System (Insects and Food) when held at various humidities.

TABLE IX.—CHANGE IN WEIGHT OF INSECTS HELD AT VARIOUS HUMIDITIES AT ABOUT 18°C.

—	Relative Humidity.			
	52 Per Cent.	68 Per Cent.	73 Per Cent.	82 Per Cent.
Initial weight (mg.)	353·7	338·4	253·5	382·3
Number of insects	13	13	14	15
Period of test (hours)	300	300	210	190
Total loss of weight of food and insects as percentage of initial weight	29·3	9·5	5·4	5·5
Food eaten (mg.)	11·1	33·9	12·5	35·7
Food eaten as percentage of initial weight of insects	3·1	10	4·9	9·3
Change in weight of insects as percentage of initial weight	−26	+0·5	−0·4	+3·8

The effect on recently laid eggs from stock insects was also tested. The nymphs survived at humidities above 55 per cent., but at lower humidities they died during the second ecdysis. At a relative humidity of 35 per cent. they died during the first ecdysis, and in dry air they failed to hatch, or died during the first instar.

When measuring the rate of loss of weight, new stadium insects were used, and were weighed separately from the food only at the beginning and end of test period. In the more humid conditions they ate sufficient food to maintain their body weight, and a relative humidity of 82 per cent. actually increased their weight by 4 per cent. In dry air they lost more weight than could be replaced from the food. Some general disturbance experienced in dry air may account for the low food consumption, and for the fact that their length of life was not increased by feeding.

Absorption from Moist Air:—Under natural conditions silverfish are not subject to dry conditions for long periods. The fact that they survived for some months when subjected to dry periods of 1, 4, and 7 days with intervening periods of one day in moist air, indicated that they could absorb moisture from the moist air. Preliminary tests indicated that the increase in weight of partly desiccated insects was proportional to their loss in weight during the preceding period in dry air. Insects which were collected while freely ranging on the walls, did not change in weight during a period of five days in moist air.

In subsequent experiments, the insects were held in dry air for various periods, and then left for four hours in air of 99 per cent. relative humidity. Every care was taken to eliminate condensation, so that the change in weight might be due only to absorption from the air.

A 300-cc. Florence flask containing 20 ccs. of 2.3 per cent. sulphuric acid was immersed to the stopper in a water bath which was maintained at 23.5°C. ± 0.02°C. Three small glass vials $2\frac{1}{2}$ in. x $\frac{1}{2}$ in. were suspended in the flask by wires. After the insects had been kept in the dry air for the required period, they

were rapidly run into one of the vials through a small glass funnel and rested on a small piece of rubber in the bottom of the tube. After four hours they were transferred to closed weighing bottles and weighed immediately, and again after drying at 103°C. for six hours.

TABLE X.—THE ABSORPTION OF WATER FROM MOIST AIR AT 23.5°C.

Previous History.	Dry Weight.	Change as Percentage of Dry Weight.	Initial Water Content Percentage.
	mg.		
From stock	36·9	− 1·1	75·4
From stock	41·9	− 0·2	72·4
In moist air, 96 hours	43·9	− 1·8	71·9
Desiccated, 4 hours	40·3	− 4·6	71·2
Desiccated, 15 hours	39·0	+ 2·1	70·9
Desiccated, 72 hours	35·4	+ 2·8	73·5
Desiccated, 96 hours	48·1	+ 3·9	69·4
Desiccated, 119 hours	34·5	+ 4·1	71·4
Desiccated, 144 hours	39·7	+ 1·5	73·0

In all but two experiments, the increase in weight was proportional to the length of the previous desiccation (Table X.). It was thought that the water content of the tissues after desiccation ("initial water content" in Table X.) would depend inversely on the length of the period of desiccation, but no such relationship was found, probably because there was some variation in the amount of food consumed during this period, with consequent variations in the amount of the water loss replaced from the food. The change in weight of insects from moist air (maintained with a dish of water in a closed tin 12 in. x 9 in. x 6 in.) was measured for comparison. These actually decreased in weight. Insects from stock suffered little change in weight, which shows that under the stock conditions they maintain a water content which is in equilibrium with an air of 99 per cent. relative humidity.

Humidity Preference.—With certain experiments it was necessary to provide a supply of moisture by means of a cotton plug in an inverted tube of water. In the open vessels the silverfish congregated on this wet surface; but in the closed vessels, the humidity was raised, and they no longer rested on the plugs.

An attempt was made to measure their response to a humidity gradient. The method recommended by Gunn, 1936, was used, but the extreme limits of humidity achieved by water and concentrated sulphuric acid, was 44 per cent. to 64 per cent. with 56 per cent. in the middle (as measured by a humatograph). The silverfish showed no preference for any region, even after the tests had been continued for one week.

Discussion:—These experiments show that silverfish are fairly susceptible to dry conditions, and that they derive at least part of their water from moist air.

No definite information about the water relation of the tissues at the time of death from desiccation could be obtained. The figure of most value seemed to be the "water content of the tissues at death." All the various species studied by other workers died when the water content of the tissues was reduced to 53–62 per cent., even though the different species lived in dry air for very different lengths of time. However, the water content at death of individual silverfish varied within still wider limits, 30–76 per cent., and even the individuals which survived desiccation the longest showed no closer similarity in this, or in the rate of loss of weight during the last days of life.

Though adaptation to dry conditions might not be expected, there seemed to be, at the higher humidities, some relationship between the amount of food eaten and the loss of weight. In air drier than 52 per cent. relative humidity the water lost was not replaced from the food eaten, but rather, less food was eaten than at the higher humidities. Buxton found that in starving meal-worms, the metabolism of dry matter was proportional to the loss of water, and the water content of the tissues remained constant. He considered this to be an adaptation to dry conditions; but later experiments with a wider range of insects showed that this could not be generalized and Mellanby, 1936, showed that metabolism is controlled solely by temperature and not by humidity.

Since the insects can take up moisture from a humid atmosphere, and since they tend to congregate near moist surfaces, dryness is probably not a limiting factor under natural conditions. Even at 60 per cent. relative humidity the loss of water was only 0.14 mg. per day.

VI. Nocturnal Habits.

Under natural conditions the silverfish feed at night. Shortly after dusk (approximately 8 p.m. in summer and 6 p.m. in winter) they emerge from the crevices of a room and move about the floor and walls usually in short runs with long pauses between. At daybreak, they return to the crevices again. They seem to be able to find shelter very easily, and, when disturbed at night by a bright light, they turn about and seek the crevice from which, presumably, they have emerged. If far from the wall, they seem to make short runs in random directions, but even then, they usually reach cover within ten minutes. This reaction to light was watched during both day and night in half-covered petri dishes some of which were exposed to strong artificial light.

The insects in the illuminated dishes always sheltered in the shaded part. During the day, even in the completely shaded dishes, the insects only occasionally moved about and fed; but as dusk fell, they moved about and fed even in the illuminated dishes.

When suddenly illuminated, the insects, after a pause of about half a minute, started to move their antennae actively. After one to two minutes they started to move about. By the end of seven minutes they reached the shadow of the piece of paper in the dish, and did not move into the light again.

Besides avoiding light in this way, the silverfish took shelter in a crevice between two glass slides and remained there quietly although they were still exposed to the light.

VII. Spraying.

The nocturnal habits of the silverfish are important in determining the effectiveness of the use of sprays as a means of control, for the insects sheltering in the crevices can seldom be reached by the spray. The vapour alone of a kerosene-lethane-pyrethrum mixture is not lethal so that they are not killed unless they come in contact with the spray droplets or the sprayed surface. In one test a cupboard of 170 c.dm. capacity was sprayed at the rate of 1 cc. per 40 c.dm. This was sufficient to make a very strong smell, but did not kill the silverfish in a petri dish protected from the falling spray by a sheet of filter paper which was removed ten minutes after the spraying.

The toxic effect of the spray on wood persisted for some hours. It was noticed that for four to six hours after the spraying of a room had been completed, dead insects could still be collected. In some cases these had crawled 3 feet to 4 feet beyond the sprayed area. The persistence of the toxic effect of the sprayed wood was further tested by confining silverfish at intervals on the surface of pieces of wood which were sprayed with a measured amount of fluid.

After a spraying of 1cc. per 14 c.dm. the insects were killed by four minutes' contact with the wood, two and a half hours after spraying. Even after the wood had been kept three days in the closed cupboard, the insects were killed by being confined on its surface for another two days.

Spraying therefore is most effective if done at night, and if at least one foot of the surface around the crevices is made thoroughly wet so that the insects cannot escape from the sprayed areas during their first moments of stimulated activity.

Both *C. longicaudata* and *L. saccharina* were used in the spray tests. *C. longicaudata* suffered a higher mortality because the torpid insects exuded a small drop of fluid from the mouth. This coagulated and fixed the head to the surface so that even when the insect recovered it could not get free.

The lethal effect of Paradichlorbenzene ("P.D.B.") and naphthalene depended on the vapour and not on contact with the insect.

VIII. Conclusion.

Whether *C. longicaudata* is a native of Australia is not known, but it is now widely distributed and it is the only one of the many silverfish in Australia which occurs in great numbers in buildings. *Thermobia domestica* Pack. and *Lepisma saccharina* L., the two common silverfish of Europe and North America are also found here, but large numbers occur only in isolated habitats.

Though the rate of egg laying is comparatively low, the long life of the adults leads to a rapid increase in numbers. For example, assuming that each female lays 56 eggs per year and that there are no fatalities, the progeny of one pair would lay 470,000 in the seventh year.

Climatic conditions in most parts of Australia are favourable for rapid development, and by its nocturnal habits, it escapes the most severe periods of heat and dryness.

It feeds on a wide variety of materials and ranges far in search of food, and probably under normal conditions lack of food does not limit its development. No natural control appears to operate and it seems that artificial control methods must be continuously applied to protect particular articles and to reduce the numbers of the insects.

IX. Summary.

The long-tailed silverfish, *C. longicaudata,* is widely distributed in Australia and is becoming a pest of increasing importance.

It is a general feeder, eating plant and animal remains as well as commercial goods such as papers, wallpapers, and artificial silk. The selective attack on wallpaper and writing and printing paper is due to the palatability of certain constituents. In wall-paper the palatable materials are the starch and dextrin sizes which are mixed with the pigment to produce the thick coloured layer on the face of the paper. In writing paper the palatable material is the chemical pulp containing degraded celluloses. Papers containing more than 45 per cent. mechanical pulp are not eaten and the unpalatable materials in this pulp are associated with the " ether extract " fraction.

The surface of papers and artificial silk can be rendered un-palatable by spraying with a 1 per cent. solution of tricresyl-phosphate in a petroleum solvent (" White Spirits ").

Digestion occurs mainly in the large crop, where the action of the gizzard is supplemented by that of cellulose digesting bacteria, and by enzymes which pass forward from the mid-intestine.

The pH of the successive regions of the alimentary canal was found by feeding the insects with indicators and noting their colour in the intestine.

Methylene blue and Sudan III were absorbed from the mid-intestine and showed that there were three distinct regions in the epithelial lining. They also stained certain organs of the body and were finally removed by the malpighian tubules.

The life cycle from the egg to sexual maturity takes two and a half to three years and the adult insect continues to grow, moult, and lay eggs for at least four more years. The successive instars can be distinguished to some extent by the relative size of certain organs and by the state of development of the gonopophyses and reproductive organs.

The insect's activities are greatly affected by the periodic ecdyses. Feeding occurs only during the first part of each stadium. Fertilization occurs after each ecydsis. Egg laying occurs throughout the summer months and on the average 56 eggs are laid by each female each year.

Yeast and ground wheat provide an adequate diet for the development of the nymphs. Adult insects have survived for three years on a diet of paper only, and for nine months without any food.

Under experimental conditions active feeding and growth begin at about 16°C. The "optimum" is 25°C., and continuous exposure to temperatures higher than this cannot be survived for long periods. Below 11°C. development stops and the insects become torpid. The distribution of silverfish in Australia in pest numbers, and their activity during the year, can be related to air temperatures.

The lethal temperatures for exposures of one hour and fourteen hours are lower in dry than in moist air, and indicate some control of the body temperature by the evaporation of body fluids. Attempts were made to measure the body temperature with a thermocouple and to measure the specific heat of the tissues.

On the average adult insects live only thirteen days in dry air, during which time the water content of the tissues is reduced from 72 per cent. to 58 per cent. They are most susceptible to dry conditions during the period of ecdysis. Insects early in the stadium can survive a greater loss of water than insects late in the stadium. Humidities above 52 per cent. are not fatal, and the water lost is replaced from the food. The insects congregate on a damp surface but do not show any preference for air of 64 per cent. relative humidity over 44 per cent. relative

humidity. Partially dried insects take up water from moist air, so that the effect of short periods in dry air is not cumulative, provided that there are intervening periods in moist air.

Their nocturnal habits are important in determining the effectiveness of spraying as a means of control. They are killed by contact with the spray droplets, or with the sprayed surface on which the toxicity of the spray persists for several hours.

From the nature of the insect's life cycle, its feeding habits, its temperature and moisture requirements and the absence of natural enemies, it is concluded that control measures must be continuously applied to keep this species under reasonable control.

Acknowledgment.

I wish to express my gratitude to all the people I have had the opportunity of consulting during the progress of this work, and particularly to Professor S. M. Wadham and Miss J. W. Raff for their helpful and stimulating advice, to Mr. G. W. Leeper for his criticism of the manuscript, to Mr. H. Womersley for identifying the silverfish, and to Dr. Heyman for interpretation of the moisture absorption experiments, to Mr. G. Ampt for the analysis of the silverfish, to Dr. W. Davies for materials and invaluable advice during the preparation of the deterrent spray.

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Appendix.

In the following table is summarized the behaviour of the various materials tested as deterrents. Usually 90 per cent. alcohol was used as the solvent, and the concentration measured in grams per cc. of solvent or else a saturated solution (S) was used. Although several concentrations of each material were tested, only the behaviour of the most concentrated solution of each is included in the table.

In some cases the decomposition of the material was appreciable only after the sprayed paper had been exposed to sunlight for two weeks. This decomposition was evident by the discoloration of the paper, or by the subsequent ready attack by the silverfish. Some of the materials acted as stomach poisons and others proved toxic before the paper was eaten. During the tests the insects were confined on the surface of the sample or were held in a closed vessel (3 in. x 6 in. x 12 in. high) so that the toxicity was caused either by contact or by the vapour. In such cases new groups of insects were used, after the paper had been exposed to the air. The effect of the vapour alone was investigated only for mercuric chloride. Paper sprayed with this material caused the death of silverfish held in a test tube, when supported 1 in. above the insects so that it was out of reach.

—	Concentration.	First Attack Days.	Toxic.		Decomposes or Volatile.	Discolours Paper.
			When Eaten.	Without Eating.		
MATERIAL.						
Phenol Derivatives.						
Acetylsalicylic acid	S.	27	—	—	—	—
Acetylsalicylic acid (Sodium salt)	5%	27	—	—	—	—
Amylmetacresol	1%	60	—	+	+	+
Beechwood creosote	10%	2	—	—	—	—
Catechol	5%	27	—	—	—	—
Chlor. betanaphthylsalicylate	—	> 240	—	—	—	+
Dibromobetanaphthol	S.	100	—	+	+	—
Dihydroxynaphthoic acid	S.	270	—	—	—	+
Dinitrophenol (2·4)	S.	27	—	—	—	—
Diiodothymol (Sodium salt)	S.	27	—	—	—	—
Diphenol	1%	27	—	—	—	+
Diphenylphenol	S.	35	—	+	+	—
Gallic acid	S.	4	—	—	—	—
"Hexol" disinfectant	—	70	—	—	—	—
Hexyl phenol	10%	180	—	+	+	—
Hexylresorcinol	1%	60	—	—	—	+
Hydroquinone	5%	27	—	—	—	—
Methylsalicylate	—	7	—	—	—	—
Metacresol	10%	20	—	+	—	—
Metacresol (Sodium salt)	10%	20	—	+	—	—
Metacresotinic acid (Sodium salt)	S.	—	—	—	+	+
Monochlorophenol (Sodium salt)	10%	70	—	—	—	+
Naphthol	S.	—	—	+	+	+
Parahydroxybenzaldehyde	5%	27	—	—	—	—
Parahydroxydiphenyl (Sodium salt)	S./2	20	—	—	—	—
Paranitrophenol	5%	—	—	+	+	+
Paranitrophenol (Sodium salt)	S	27	—	—	—	—
Paratertiaryamylphenol (Sodium salt)	2%	60	—	+	+	+
Paracyclohexylphenol (Sodium salt)	S.	>200	—	+	+	—
Resorcin	5%	27	—	—	—	+
Saliginin	S.	27	—	—	—	—
Sulphosalicylic acid	5%	30	+	—	—	—
Sulphosalicylic acid (Sodium salt)	S.	60	—	—	—	+
Tannic acid	4%	30	—	+	+	+
Thiodiphenylamine	S.	—	—	—	—	+
Thymol	S.	60	—	+	+	+
Tricresylphosphate	1%	—	—	—	—	—
Tribromphenol	S.	180	—	+	+	+
Other Compounds.						
Abietic acid	S.	14	—	—	—	—
Aloes	S.	40	—	—	—	—
Ammoniacum	S.	14	—	—	—	—
Aluminium chloride	4%	35	—	—	—	—
Antimony sulphate	S.	15	—	—	—	—
Anthracene	S.	15	—	—	—	—
Barium oxalate	S.	31	—	—	—	—
Barium thiosulphate	S.	5	—	—	—	—
Borax	17%	13	—	—	—	—
Cetyltrimethylammonium bromide	—	1	—	—	—	—
Citronella	—	60	—	—	—	—
Copal	S.	14	—	—	—	—
Malic acid	5%	17	—	—	—	—
Mercuric chloride	0·5%	30	+	—	—	—
Mercuric cyanide	S./4	30	+	—	—	—
Mercurochrome	0·3%	14	+	—	—	+
Mercurosal	1%	50	+	—	—	—
Metaphen	0·2%	20	+	—	—	—
Pyridine	5%	2	—	—	—	—
Sea Water soap	—	4	—	—	—	—
Sodium fluoride	S.	26	+	—	—	—
Stannous ammonium chloride	4%	20	—	—	—	—
Stannous chloride	S.	25	—	—	—	—
Tartar emetic	S.	> 240	+	—	—	—
Tetramethylthiuramdisulphide	—	20	—	—	—	—
"Titrol"	10%	5	—	—	—	—
Triethanolamine	1%	60	—	—	—	+

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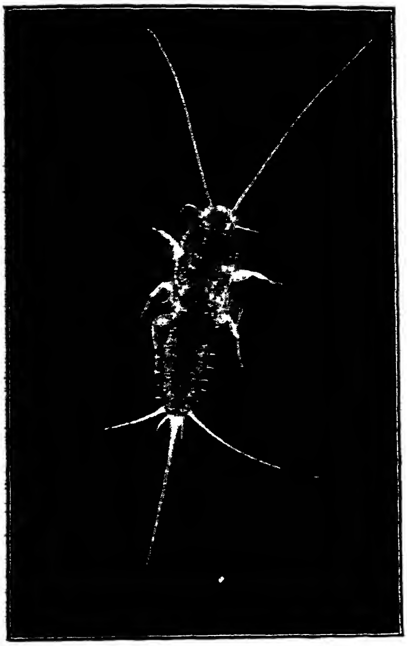

FIG. 1.

FIG. 2.

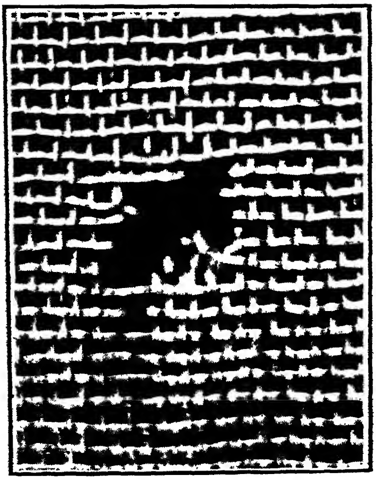

FIG 3.

FIG. 4.

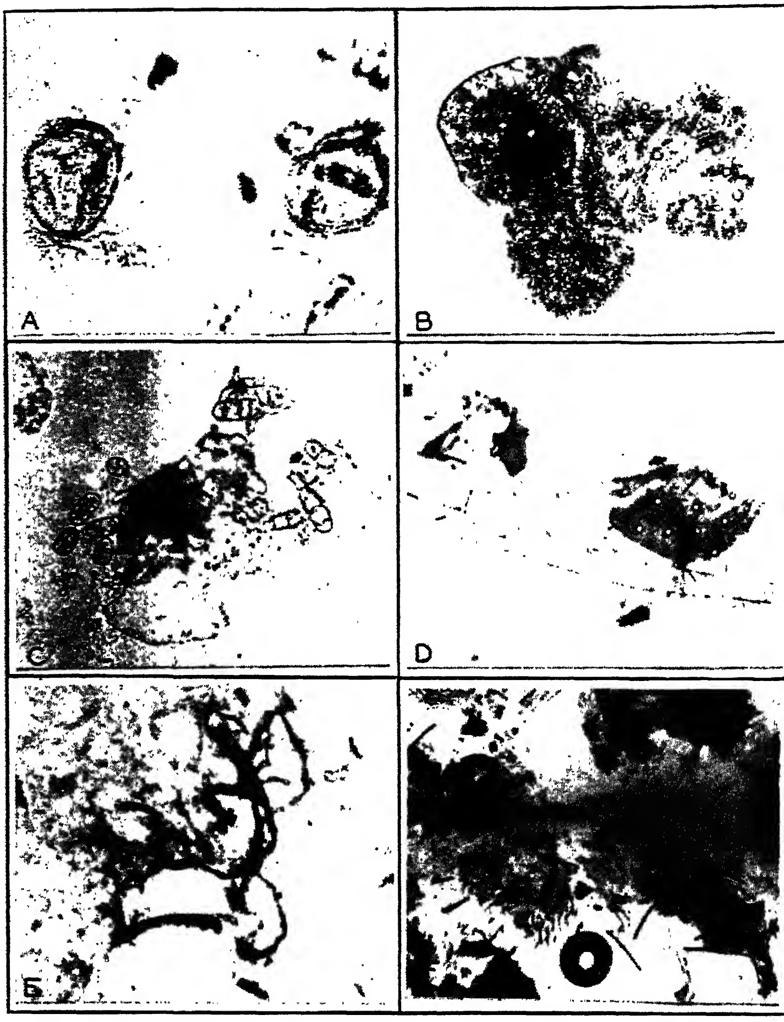

Fig 1.

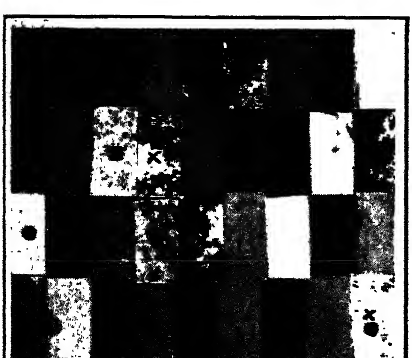

Fig. 2

	RED	DEXTRIN	DEXTRIN	STARCH	RED DEXTRIN			
RED	DEXTRIN	DEXTRIN	RED DEXTRIN			RED		STARCH
STARCH	RED		DEXTRIN	RED STARCH			RED	
STARCH								RED STARCH

Fig. 3

Explanation of Plates

Plate 1.

Fig. 1.—*Ctenolepisma longicaudata* Esch.

Fig. 2.—Damage on wallpaper × 138.

Fig. 3.—Damage on artificial silk net × 8.6.

Fig. 4.—Damage on artificial silk fabric. × 4.5.

Plate 2.

Fig. 1.—Fragments from contents of crops.

A. Pollen grains. × 276.
B. Edge of leaf. × 62.
C. Fungal spores. × 318.
D. Chitin showing bases of setae × 396.
E. Fibres from paper stained with Herzeberg's reagent. × 76.
F. Chitin and setae. × 310.

Fig. 2.—Section of wallpaper samples after test of one week.

Fig. 3.—Key to composition of samples shown in Fig. 2. The unlabelled samples contain the sizes, gum, glue and casein.

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ART. IV.—*The Question of Recent Emergence of the Shores of Port Phillip Bay.*

By EDWIN SHERBON HILLS, Ph.D., D.Sc.

[Read 8th June, 1939; issued separately, 1st March, 1940.]

In spite of the definite terms in which a belief in Recent emergence of the shores of Port Phillip Bay has been expressed by some authors, the question has of late become controversial. Jutson has recently reviewed the evidence (1931), but although he adduced much new information bearing on the subject, he was unable to draw any decisive conclusion.

The author has re-examined the shores of the Bay, in order to discover criteria that might perhaps settle the matter. The eastern shores, from which little evidence concerning changes in sea level had formerly been obtained, were traversed from the Quarantine Station at Portsea to Brighton, and critical stretches of the western shores were also studied in detail. It may be stated in advance that what appears to the author to be definite evidence of Recent emergence has been observed at practically all localities where the conditions of erosion and deposition are such as to favour its preservation.

I. The Eastern Shores.

RAISED SHORE PLATFORMS.

Three difficulties present themselves in the interpretation of shore platforms. Firstly, where the coast is composed of horizontal or gently dipping strata of different degrees of resistance to weathering and erosion, not only may the development of normal shore platforms between low and high water mark be interfered with, but also, rock ledges formed by resistant beds above high water mark may simulate raised abrasion platforms. This is well illustrated at Rickett's Point, where an abnormally broad shore platform has been developed on the upper surface of the resistant Red Beds, which, there, is situated between low and high water levels. The Red Beds rise towards the south, and at Table Rock a well marked ledge, above high tide level, has been produced on their upper surface by the more rapid weathering and erosion of the overlying softer rocks. With such geological conditions, especially where differential weathering and erosion are less obvious, the recognition of any slightly elevated abrasion platform that might be present is difficult.

The second difficulty is related to the amount of emergence. It is well known that no immediately obvious raised shore platforms occur around the shores of Port Phillip, and it was therefore realized that the amount of any Recent emergence which might be discovered would probably be small. Under these circumstances raised abrasion platforms might still be subjected to the attack of storm waves. They would never have been very broad, and after erosion only remnants of them would remain. These would be difficult to distinguish both from rock ledges and from irregularities in the normal shore platforms.

The third difficulty is the fundamental one that the principles underlying the development of shore platforms, even with a stationary sea level and uniform rocks, are by no means fully understood (see e.g. Bartrum, 1935). Where possible emergence or other changes in the physiographic conditions introduce complications, the interpretation of shore platforms becomes very involved, and the author realizes that more intimate studies than he has yet been able to undertake may require some modification of the ideas put forward in this paper.

Raised Shore Platforms in Granite.

Shore platforms that are regarded as "raised" abrasion platforms by the author, occur at the foot of Oliver's Hill, Frankston, and 1 mile north-east of the mouth of Tanti Creek, Mornington. At the north-eastern corner of Dromana Bay, a granite platform, whose interpretation is open to some doubt, occurs above high tide level. Throughout the descriptive portion of this paper the words "raised" and "uplifted" will be used with reference to emergence due either to eustatic movements of sea level or to tectonic movements.

At the above localities the raised platforms range up to about 3 feet above high tide level. At each there is also a well-developed abrasion platform now being cut between high and low water levels. These latter platforms are covered with a veneer of rounded pebbles and small boulders in various degrees of dispersion. In places, pebble beaches have been built up above low water mark; elsewhere the pebbles are widely scattered, and in places sand occurs on the platform.

At Frankston and Mornington water-worn pebbles rest upon the raised platforms (pl. III, fig. 1). It has been suggested to the author that these and similar high level pebble beds around the eastern bayside may be storm beaches. Evidence will be brought forward below to indicate that this is not the correct interpretation, but in the present context it is desirable to emphasize that the pebbles rest upon definite platforms, now some feet above high water level, which have been cut in uniform massive granitic rocks. Horizontal jointing in these granites cannot be regarded as determining these platforms, for the

granites of the coastline in the Frankston, Mornington, and Mount Martha districts are, with very local exceptions, extremely closely jointed and shattered by steeply dipping joint planes, major horizontal joints being absent. No obvious petrological differences between the rocks of the presumed raised platforms and of the normal platforms below them were observed.

At Frankston and Mornington the raised platforms are seen in section at the foot of the cliffs, although at Frankston part of the platform has been laid bare of its cover of pebbles and talus. In Dromana Bay, on the other hand, remnants of the presumed raised platform rise as table rocks above the normal shore platform, and are not covered with pebbles.

It may be observed in a profile view that these table rocks have a general similarity in elevation, although rising gently towards the base of the cliff. There the raised platform is better preserved (pl. III., fig. 2), and in one locality a well marked notch is situated at the junction of the cliff face with a platform remnant. The tops of the presumed platform remnants range from about 1 ft. 6 in., to 3 ft. 6 in. above the platform now being formed, and are still subject to wave attack.

Passing away from the commencement of the granite cliffs near Dromana, the platform remnants become lower and smaller, until none are preserved. Where it is well developed, the platform resembles in some respects the storm wave platforms described by Bartrum (1935), being in places above high tide level, and having a steep drop at its seaward edge, where a normal profile is developing. Storm wave platforms are, however, rarely developed in massive igneous rocks; they are found only at localities subject to very vigorous wave action, and are backed by cliffs that show no signs of weathering. It is probable, too, that a considerable tidal range aids their formation. In none of these respects are the conditions in Dromana Bay comparable. The tidal range is small, only 3 to 4 feet; the cliffs are weathered, the rocks are massive, and violent waves of an intensity commensurable with those on exposed ocean coasts are not formed in Port Phillip.

At the commencement of the cliffs (see pl. III., fig. 2, right hand side) the appearance is given that as the detrital material which overlies the granite at this point is eroded away, the cliff so exposed is not homogeneous, but has resistant rock near its base overlain by softer rock above. Some suggestion of this is also to be seen in small coves cut into the granite, and it may be that the rock of the platform is more resistant to erosion than that above it. This in turn can perhaps be related to the saturation of the rocks below high tide level, as in the formation of platforms of the Old Hat type (Bartrum, 1935). In the present instance, however, the platform is not horizontal either along the coast or in profile, and is in part above high tide level.

It must therefore be further postulated, following the above assumptions, that emergency has occurred accompanied by tilting, and that wave erosion of the resistant rock above present high tide level has produced the seaward inclination of the platform.

RAISED SHORE PLATFORMS IN TERTIARY SANDSTONES.

Localities where these have been observed are as follows:—Between Grice's Creek and Davey Point; near the mouth of Tanti Creek, Mornington; and on the north side of Fisherman's Point, Mornington. These platforms are essentially similar to those in the granites at Frankston and Mornington. They are overlain by deposits of water-worn pebbles similar to those on the normal shore platforms at each locality. Their seaward edges are being eroded during storms, and thus the platforms and their covering pebble beds are seen in section at the back of the present beaches (pl. IV., fig. 3).

Between Grice's Creek and Davey Point the platform is well exposed on a small point, where a thick kitchen midden rests on the pebble bed (pl. III., fig. 3). At this point the platform is about 2 feet above average high water level. At Tanti Creek the platform is seen to rise in the cliff section south of the creek, on to the slopes of a hill. Where it is flat, nearer the creek, it is about 3 feet above high water level. Where it rises on to the hill, boulders derived as talus from the latter can be seen to rest upon the slopes. These are not water-worn, but as the slopes flatten and the pebbles pass down on to the platform, they become rounded, pitted, and covered with a ferruginous coating, exactly resembling in these features the pebbles and boulders on the present beach.

At Fisherman's Point the platform is about 3 feet above average high water level, and the base of the pebble bed that rests on it has been cemented by calcareous infiltrations.

As with the granite platforms, those cut in Tertiary sandstones at the above localities are clearly not determined by differences in the rate of weathering and erosion of the strata. In all their features, excepting their elevation above sea level, they closely resemble the platforms now in course of formation at existing sea level.

THE HIGH LEVEL PEBBLE BEDS.

The suggestion has been made that the pebble beds which rest upon the above-described platforms, and similar high level pebble beds at various localities around the eastern shores of the Bay, are storm beach deposits. Several considerations may be urged against this view

Firstly, it is a matter of experience and observation that no marine deposition has gone on at the level of the pebble beds for a long period of time. On the storm beach hypothesis it is necessary to postulate that the pebble beds are ancient storm beaches, and that the physiographic conditions have changed since they were built up. It is indeed clear that they formed before the aborigines began to make extensive use of the shellfish along the shores for food, since no kitchen middens underlie them. On the other hand, they are in every instance covered either by kitchen middens or by talus from the cliffs. It is evident that the platforms and pebble beds afforded dry, flat camping grounds, conveniently situated near the shore. The growth of vegetation on the middens and talus which cover the pebble beds is a further indication that for a long period they have been out of reach of the waves, except at rare intervals during severe storms. The latter, however, have in no known instance added to the deposits, but have invariably tended to erode them away.

In consideration of the evidence concerning the nature of the pebble beds and the rock platforms on which they rest, it appears reasonable to link the two, and to regard the platforms as raised abrasion platforms, the pebble beds as beach deposits formed by wave action on these platforms before they were elevated. The analogy with the platforms now being cut, is then very close.

VEGETATED CLIFFS.

The long stretches of vegetated cliffs that lie behind the back-shore deposits in the majority of small bays on the eastern shores of Port Phillip are considered to be of some significance in relation to uplift (pl. III., fig. 3). If the protecting beach deposits are to be regarded as due to normal progradation at present sea level, then some change in the conditions of erosion and deposition along the bayside must be postulated to account for the general cessation of erosion, except at headlands and places where the nature of the rocks or the presence of deep water offshore favours it. No reason for such a change has been put forward, and the author can suggest none Furthermore, the nature of any such change would be the reverse of that which might be postulated to account for the high level pebble beds, if these are regarded as storm beaches. In the latter case, retrogradation must be regarded as proceeding; in the former, progradation.

On the other hand, a slight Recent uplift would fit the observed facts very well, accounting for both the raised pebble beds and the vegetated cliffs. Such an uplift would have the effect of temporarily removing the base of the cliffs from the zone of active wave attack. Before they could be again subjected to such attack, that portion of the abrasion platform which had been

raised above high water level would have to be removed. It is considered that this has occurred on the headlands and in belts of soft rock on the eastern shores of the Bay. Elsewhere various stages in the removal of the platforms are to be seen, the common condition near the headlands being shown in pl. IV., fig. 3. Here the raised abrasion platform and its covering pebble bed are exposed in section. Further from the headlands, erosion would be subordinate to deposition, and the raised platforms would be covered with blown sand or low beach ridges, forming a dry backshore zone on which vegetation could become established, so further protecting the cliffs. This is to be observed at many localities, such as Portsea, Sorrento, and Rickett's Point, where bathing boxes, boat sheds, and even dwellings have been built on the backshore deposits. In a small bay adjoining Table Rock, between Rickett's Point and Beaumaris, a pine tree is well established on the grass and scrub covered backshore.

Raised Sandy Beaches and Shell Beds.

Commencing at the "First Settlement in Victoria," near Sorrento, and extending with few interruptions to The Rocks at Dromana, is a flat stretch of country, the seaward edge of which is marked by a low cliff. This gradually descends from 8 or 10 feet above ordinary high water near Sorrento and Rye, to only 1 foot or so at The Rocks. At the First Settlement, shell beds occur near the base of this low cliff. These first appear on the flanks of a cliff composed of Pleistocene dune limestones, where unworn *Arca trapezia* occurs, together with gasteropods and paired and single valves of other pelecypods. No systematic collection from these or the other shell beds around the coast has been attempted. The specimens collected were the commonest at each locality, and they were submitted to Mr. F. A. Singleton, who kindly determined them. All are referable to species now living, but it is notable that oysters and Arcas, which are common in the shell beds, are now extremely rare in Port Phillip. Indeed it is doubtful if *Arca* now lives in the Bay, although it occurs in Western Port.

At the First Settlement the *Arca* band passes up on to the flanks of the Pleistocene dune, ascending to a height of 5 to 6 feet above ordinary high water level. It descends within about 1 chain towards the east, passing into horizontal shell beds whose upper surface is about 3 feet above average high water level. *Arca trapezia* was not obtained from these shell beds, which, however, contained numerous oysters (*Ostrea* cf. *sinuata*) and other species of mollusca which may all be collected on the present beaches.

Towards Rye the shell beds pass into well stratified beach sands containing only isolated shells. These sands have developed a calcareous *B* soil-horizon about 4 to 5 feet above

ordinary high water, and the soil is overlain by a uniform and extensive kitchen midden. Between the First Settlement and the White Cliff at Rye, old sand dunes overlie the above-described beach deposits in places. The top of the beach sands can be discerned beneath the dunes as a horizontal band which breaks the sandfall slope of the cliffs. These dunes are therefore younger than the beach sands into which the shell beds at the First Settlement pass, while these shell beds are in turn younger than the Pleistocene dunes at the latter locality. The younger dunes, although calcareous, are very little consolidated, and in many places fall away at the angle of rest of the sand, whereas the Pleistocene dunes are consolidated. At a point about 1 mile west of the Canterbury jetty, between Rye and Sorrento, fossilized bones of a bird were obtained from the younger dunes (pl. IV., fig. 2). These were examined by Mr. G. Mack of the National Museum, who states that they probably belong to a genus of Procellariiformes (Tubinares), approaching the Giant Petrel (*Macronectes*) in size. They are definitely not *Puffinus* (Mutton bird). The bones are not mineralized, and their reference to a type of bird that is still common around the coast is a further indication of the youth of the dunes as compared with those of Sorrento, from which bones of an extinct species of kangaroo have been obtained (Gregory, 1902).

In view of the above evidence and the fact that no extinct species have been obtained from the shell beds, these and the overlying dunes are both regarded as Recent.

Between Rye and The Rocks no shell beds were observed, but at all localities where exposures were visible, stratified beach deposits ranging from fine sand to coarse broken shells were found to underlie the kitchen middens and superficial sand drifts along the coast. The elevation of these beach deposits ranges up to about 4 feet above high water level. They are in places overlain by low sand ridges with intervening swales.

The above beach deposits and shell beds appear to have been originally laid down below high water mark, to judge by similar formations along the existing beaches. This is indicated by the arrangement of the shells in well-defined layers, the majority lying with their convex surfaces uppermost. The common occurrence of paired valves and of unworn shells, even of fragile types, further points to deposition below the swash mark, possibly between low and high water level, or even lower. In the beach sands the stratification is well defined by coarse and fine layers, or by black bands rich in magnetite, ilmenite, and other heavy minerals such as zircon (pl. IV., fig. 2).

There can be therefore no doubt that emergence has occurred in this district. Any suggestion that results simulating emergence might have been caused by the constriction of the mouth of

Port Phillip, due to the formation of the dunes of the Sorrento peninsula, cannot be substantiated. It has been considered that this constriction would cause a reduction of high tide level in the Bay, but the raised beach deposits are younger than these consolidated dunes, and therefore their emergence cannot be related to the above cause. The gradual fall in elevation of the raised beaches towards The Rocks indicates that their emergence was caused, at least in part, by tectonic movements.

THE CEMENTED BAND AT PORTSEA.

An unusual feature shown in the cliffs at Point McArthur, near Portsea, is probably of some significance with regard to uplift. The calcareous Pleistocene dunes at this locality are consolidated, but about 2 feet above high tide level they are cemented by secondary calcium carbonate into an especially resistant band, which is about 1 ft. 6 in. to 2 feet thick. This hard band traverses the inclined bedding planes in the dunes indiscriminately, and, as levelled from one side of a small cove to the other, is horizontal (pl. IV., fig. 1). Beneath the resistant band a wave notch has been excavated.

The existence of the band in the cliff face, above high tide level, suggests that some change in sea level has occurred, since no factor can be suggested which would operate at such an elevation to induce cementation of the dunes. It is probable that the hard band was formed by deposition of secondary calcium carbonate in the body of fresh water that exists in the dunes at about high tide level. With a stationary sea level, the hard band would then appear in the cliffs at high tide level, and it is suggested that its present elevation of about 2 feet has been brought about by an emergence of this order of magnitude.

THE CARRUM SWAMP.

In the district between Mordialloc and Frankston the coast is fringed with a series of sand ridges. Behind these ridges is the Carrum Swamp, which before it was drained and cultivated was about 2¾ feet above the level of highest observed spring tides at the mouth of Mordialloc Creek, or about 4½ feet above ordinary high water. The shallow alluvium of this swamp overlies sand containing marine shells of the same species as are now found in Port Phillip. *Arca trapezia* also occurs in these sands, the level of which in the northern part of the swamp is about 3 feet or less below the present surface of the drained swamp alluvium.

The Carrum Swamp is bounded on its inland side by a second arcuate line of sand ridges, along which Wells' road runs, being so situated because the ridges are not subject to flooding as is

the land on either side. An excellent map on which the above features are shown in detail is in the possession of the Lands Department, and was used in the preparation of fig. 1.

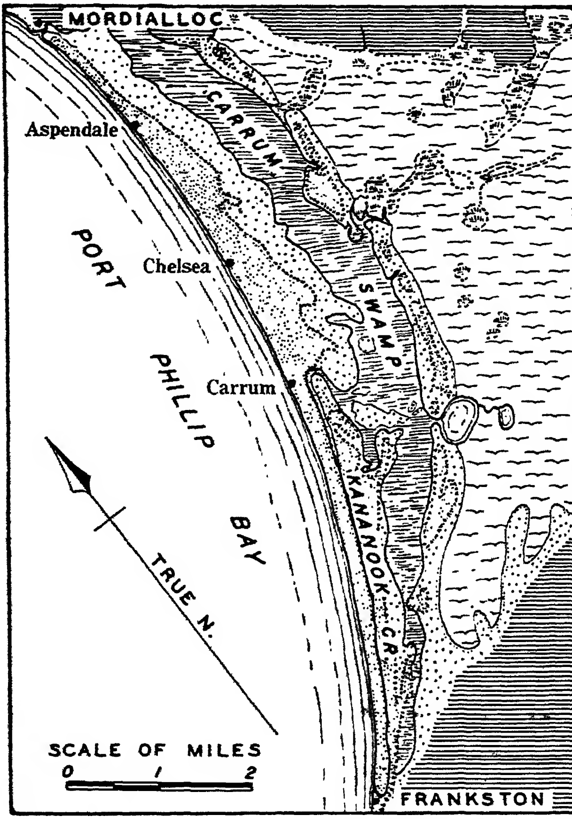

Fig. 1.—Map showing the coastal and inland sand ridges between Mordialloc and Frankston. Close stippling, high sand ridges, open stippling, low sand flats, originally covered with reeds and tea tree. Horizontal ruling, high land north and south of the swampy areas.

It is clear that at an earlier date the shoreline was situated along the Wells' road sand ridge. The retreat of the shore to its present position was then brought about by some sudden change. If this had come about by normal progradation and building of beach ridges, the latter would occur in the Carrum Swamp. No beach ridges occur there, and the sudden retreat of the sea for a distance of over 1 mile is best accounted for by postulating uplift. This is supported by the greater elevation of the alluvium behind the Wells' road ridges than that in the

Carrum Swamp (10 feet above highest spring tides as against $2\frac{3}{4}$ feet). The shell beds may have been uplifted, or they may have been laid down in a lagoon formerly situated between the Wells' road sand ridges and those along the new coastline. It is difficult to decide on this point in view of the settling down of the swamp deposits since they have been drained.

The course of the Kananook Creek, which is diverted southwards near Carrum and flows for $4\frac{1}{2}$ miles parallel to the coast, to reach the sea at Frankston, is notable. The creek occupies a marshy depression between two well-defined but complex sand ridges whose origin is not yet clear. It is highly improbable that the creek should have suffered such an extensive diversion simply as a result of the formation, by normal progradation, of a series of beach ridges barring its mouth. It occupies an unbroken trough between the two main ridges, and is too sluggish to have cleared this for itself, being only at about sea level throughout its length. A slight uplift after the formation of an earlier coastline along the seaward edge of the ridge along which the railway runs at Seaford would, however, have probably led to the formation of the second ridge, on which the Point Nepean road is situated, leaving a swale between the two. This would be then used by the creek.

THE YARRA DELTA.

On the map published by Selwyn (1854), the superficial deposits of the aggraded area at the head of Hobson's Bay, known as the Yarra Delta, are described as "Recent upheaved estuary bottom, consisting of beds of sand and clay with recent shells resting on red Tertiary sandstone." Sections given by Selwyn (1854) and by Lucas (1887) show that the surface of the sand formations fringing the seaward edge of the West Melbourne Swamp rises to $7\frac{1}{2}$ to 10 feet above high water level. Parallel ridges described as "blown sand" are more probably beach ridges, as described by Jutson (1931), and these rest upon "sands and Recent shells." These sands are in places current bedded, and are regarded as marine by Selwyn and Lucas. They are 2 feet above high water level in some parts.

II. The Western Shores.

As remarked upon by Jutson, these are physiographically distinct from the eastern shores, long stretches being flat and undergoing progradation, while the eastern shores are cliffed in many places. An important area which has been much discussed is that between the Williamstown Racecourse and the Military Reserve at Altona. Near the Williamstown Racecourse occur the so-called Altona shell beds, which have been described by Hall and Pritchard (1897), Grant and Thiele (1902), Pritchard (1909, 1910), and by Jutson (1931). The shells are all of

living species, and all palaeontologists who have referred to them agree that they are Recent (see Singleton, 1935). Grant and Thiele showed that the shell beds are 8 feet thick, the top being $7\frac{1}{2}$ feet above high water level. I am informed by Dr. H. S. Summers, who collaborated in the levelling, that the datum used was the swash mark of the highest observed tides in the neighbourhood. These authors noted that the shells occur in distinct layers, with marine and estuarine types interbedded. They concluded that the beds are therefore not storm beaches, and that an uplift of at least 10 feet has taken place since they were deposited. Pritchard, however, decided that they are storm beaches, and Jutson described them as beach ridges probably formed by storm waves at existing sea level.

In regard to their nature, the following points are of importance. The beds are well stratified and not current bedded. Individual bedding planes can be traced for some yards both parallel to and at right angles to the coast. They contain thin-shelled forms in a perfect state of preservation, and a majority of the concavo-convex shells lie with their convex surfaces uppermost, indicating that they were deposited below high water level, out of reach of the turbulent swash of waves breaking on the beach. These features are in the author's opinion quite sufficient evidence that the beds are not storm beach ridges, for in these stratification is typically irregular, or even absent, and thin-shelled forms are broken.

The relationship of the beds to the other shell and sand ridges of the district is also significant. Jutson has given a general description of these ridges, and of the associated swamp deposits with marine shells that occur on the beds of three shallow ephemeral lakes in the Altona district. This district has been mapped on a scale of 200 feet to 1 inch under the direction of the author, and fig. 2 is based on this work. In the vicinity of Altona and Seaholme townships the ridges have been disturbed and cannot be traced in detail. North-east of Seaholme the ridges are composed in part of shelly limestone similar to the type locality near the Williamstown Racecourse (fig. 2), and in part of sand with scattered shells. The ridges rest upon the surface of the Newer Volcanic basalt, which appears in some of the intervening troughs. Along the seaward edge of the basalt is a rather sudden drop of a few feet to an area of tidal flats and low beach ridges, the land on the higher side of this drop being entirely out of reach of wave action at existing sea level. This stretch of coast faces the south-east, a quarter from which storm winds are extremely rare. The fetch of such winds is also relatively short, and the water offshore is very shallow. It is therefore scarcely conceivable that storm waves of sufficient intensity to flood the basalt plain, and to deposit beach ridges on it up to 8 feet above the highest known high water mark,

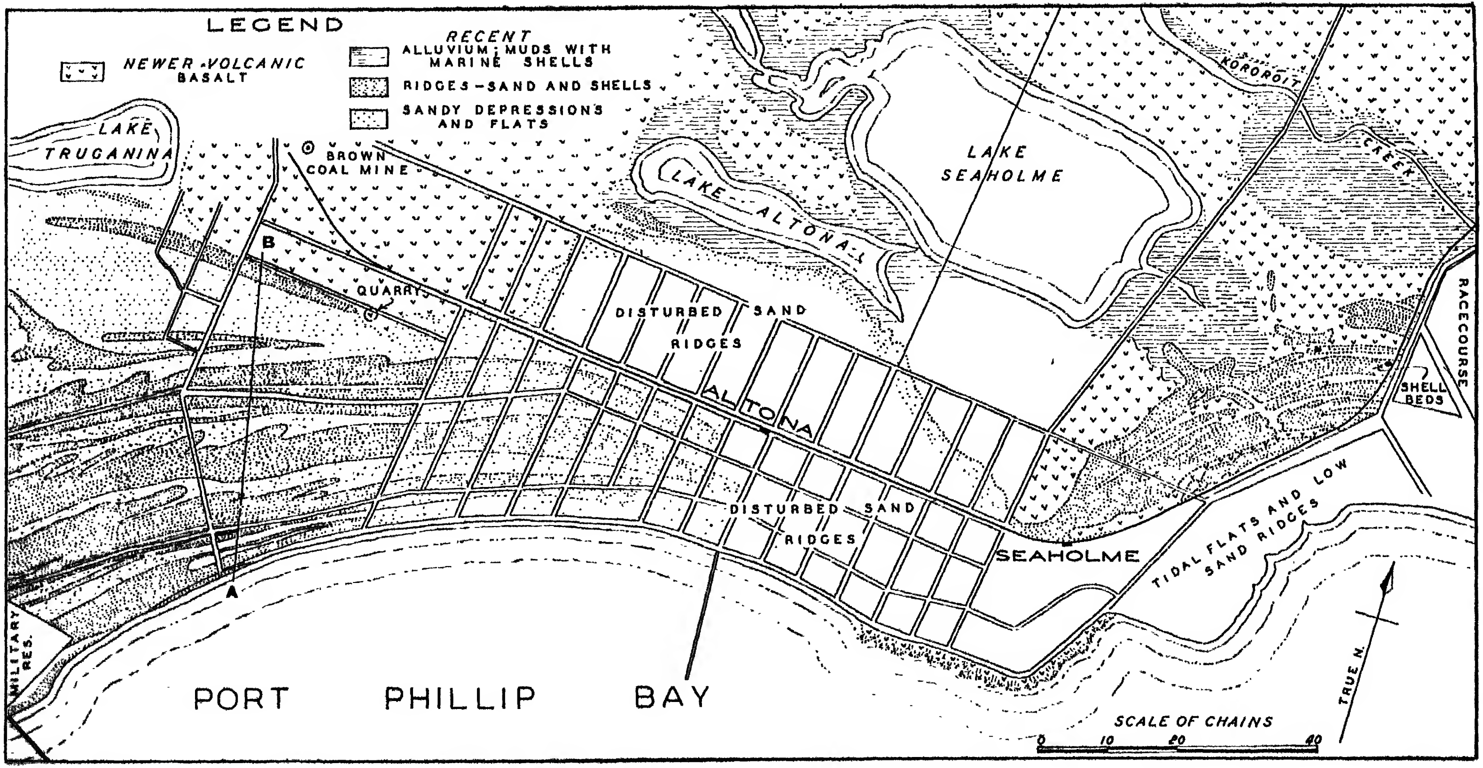

Fig. 2.—Map of the sand and shell ridges in the Altona district.

should ever have been generated in this area under the existing conditions. Furthermore, even if such a possibility could be entertained, no good reason can be suggested for the formation of an orderly succession of such ridges at gradually decreasing elevations towards the coast.

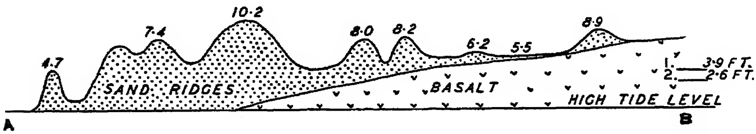

FIG. 3.—Section along the line *A–B* in Figure 2. Vertical scale, 1 in. = 22 ft.; horizontal scale, 1 in. = 14 chains. 1. Elevation of marine shells *in situ* in muds, Lake Truganina. 2. Elevation of redistributed marine shells on the bed of Lake Truganina.
Note.—The ridge nearest *A* is a beach ridge formed at existing sea level.

The view that these ridges are not beach ridges is further supported by their external form. A beach ridge is typically high compared with its breadth, owing to its formation by waves breaking within a narrow zone along the foreshore.

The ridges at Altona and Seaholme, on the other hand, are relatively low and broad. A ridge 4 chains wide is, for example, only 4 or 5 feet above the neighbouring swales. That wind erosion subsequent to their formation was not the cause of this is indicated by the approximate parallelism of the bedding planes in the shell beds with the upper surface of the ridge they form, and also by the preservation of the swales between the ridges, which would have been partially obliterated by blown sand had the tops of the ridges been removed by the wind. Beach ridges formed at existing sea level are present in this district. They are quite distinct in form from the other ridges whose origin is in question.

Of particular significance, too, are the shape of the ridges in plan, and their spacing. Regular spacing of beach ridges, with intervening swales, can be brought about with a stationary sea level if a headland nearby is retrograding, so causing regular variation in the trend of the littoral currents. In the present example no such factor has been effective. The ridges have been "plastered" along an extensive stretch of flat coastline, from Williamstown to Werribee. Under these circumstances, and with a stationary sea level, beach ridges would have been piled successively one against the other, the intervening depressions being irregular and narrow. Actually, they are well spaced, and in places are separated by wide sandy flats, as for example south of the old brown coal mine. In addition, some of the ridges, especially in the Altona area, exhibit peculiar lobate or digitate projections from their landward sides (fig. 2). These projecting spits run off the main ridges towards the north-east. No beach ridges known to the author exhibit such features.

If the beach ridge hypothesis be rejected, it remains to indicate the mode of origin of the ridges and swales. The great breadth of the ridges compared with their height, the variation they show from shell beds to sand with included shells and pebbles, their regular spacing with low troughs between them, and their lobate landward edges suggest that they are raised banks such as are common off the existing beaches around the Bay. Examination of these banks has revealed that, as with the ridges, their seaward edges are typically smooth, but their landward edges are either lobate or furnished with oblique minor ridges running off at an acute angle into the troughs. Such banks occur in series, with well-defined troughs between them. In structure, external form, and spacing they are closely analogous to the Altona ridges.

It is therefore suggested that the underlying form of some at least of the ridges is that of submarine banks formed when the level of the sea was sufficiently high to cause it to flood over the basalt plains in the areas where the above described ridges occur. It appears probable that, either at this time or as the sea retreated, these banks were added to in places by the growth of beach ridges, but the shell beds near the Williamstown Racecourse, and the lobate ridges near Altona, are regarded simply as upraised submarine banks.

Shell Beds in Swampy Areas.

The elevation above high water mark, of marine shells *in situ* in black mud on the banks of Lake Truganina was determined as 3½ feet. These muds contain paired valves of pelecypods, which are little disturbed and approximately in their position of growth. Comparable deposits now forming are found at half tide level or lower, and it is clear that emergence must have occurred, raising these marine shells above sea level. Bearing in mind the fact that similar black muds containing marine shells are now forming only below high tide level, it is also clear that the shell beds exposed at high tide level in the banks of the Kororoit Creek and those slightly above high tide level beneath the flats north of the Williamstown Racecourse must have also been uplifted.

Such shell beds are common along the eastern side of the Bay, and it may be emphasized that in deciding whether or not they have been uplifted, it is essential to remember that back-shore deposits and beach ridges, which can be built up above high tide level by normal progradation, have irregular stratification. They typically contain worn and broken shells, paired valves and complete delicate forms being rare or absent. Furthermore, they are never composed of shells set in fine mud, but consist of the coarser grades of sediment available along the shores.

Thus, the shell beds above mentioned, and similar occurrences at Werribee, Duck Ponds Creek, Corio Bay, and elsewhere (see Jutson, 1931, for details), which are now at or above high tide level, must have been uplifted. Indeed, at the Duck Ponds Creek the shell bed falls from about 5 feet above sea level near the Geelong road to sea level about a quarter of a mile downstream, and then passes beneath the waters of Corio Bay. The uplift at this locality was therefore tectonic. It has already been pointed out (Hills, 1938) that the raised Recent shell beds at Portarlington were probably elevated by earth movements, and Chapman (1929, Chap. XIV.) also favours the view that the emergence of the Recent deposits described by him was due to the same cause.

Point Lonsdale.

The thick shell beds that occur on the floors of the shallow salt and freshwater lakes in this district are most impressive. Concavo-convex shells are almost all arranged with their convex surfaces uppermost, and the deposits are well stratified, with gently inclined bedding planes. Dr. H. S. Summers informs me that a line of levels from the shores of Swan Bay to the top of the shell beds near the lake called Lake Lonsdale by Jutson, was run by him in collaboration with Mr. E. Broadhurst. The upper parts of the shell deposit are at least 1 foot above highest high water mark in Swan Bay. Furthermore, it is obvious in the field, as noted by Jutson, that the floors of some of the smaller lakes in the district, including the freshwater lake, are higher than the bed of Lake Lonsdale. Marine shell beds also occur around these lakes, so that the indications of uplift are further supported.

Raised Shore Platforms in Basalt.

From the south-eastern corner of the Rifle Butts at Williamstown, to the wheat stacks near the old Fort, the coast is formed of Newer Volcanic basalt. In this locality a well-defined low cliff marks the edge of the basalt plains, and between this cliff and the present shoreline is a basalt platform some 20-30 yards wide. This is not normally subject to wave attack, but parts of it were awash during the exceptionally high tides that accompanied the floods of December, 1934. The platform is grassed, and is covered with large loose boulders of basalt resembling those on the present beach. At the seaward edge of this platform there is in places a drop of about 3 feet to the present beach. Marine shells occur in black soil on the platform, and also in the joint planes of the basalt. The storm beaches built at the back of the existing beaches extend up for a short distance on to the seaward edge of the platform, but no further, and the suggestion is very strong that the platform is a raised

abrasion platform backed by a former sea cliff. The summit of the latter is approximately 5 feet above the platform, and this in turn 2 to 3 feet above the present abrasion platform.

Evidence that the latter is a true abrasion platform and not merely the original surface of a flow is afforded by the presence near the old fort of a small lava blister with its summit eroded away. No alternative explanation which would adequately explain the existence of the low scarp, here regarded as a former marine cliff, and also of the boulder-covered platform above high tide level can be suggested by the author.

III. Date of the Emergence.

The age of the emergence to which the above-described features may be ascribed is shown by the following lines of evidence:—

1. At Point Lonsdale and Sorrento the raised shell beds post-date the consolidated Pleistocene dunes.

2. Between Sorrento and Rye the raised shell beds and beach deposits post-date the consolidated Pleistocene dunes, but ante-date other calcareous dunes, which are not consolidated. The latter have yielded bones of a bird similar to a living form, but they are fixed by vegetation, and clearly were formed under physiographic conditions different from those now obtaining. It is suggested that there is no considerable difference in age between these dunes and the underlying raised beach deposits. This is indicated by the absence of weathering or erosion of the surface of the beach deposits upon which the dunes rest (pl. IV., fig. 2).

3. The palaeontology of the Altona shell beds has been discussed by Hall and Pritchard, by Grant and Thiele, and by Pritchard. Singleton (1935) has also referred to them. They contain only living species, and are regarded as Recent.

4. Chapman (see Jutson and Coulson, 1937) has shown that the Portarlington shell beds also contain only living species, and there is no good reason for regarding them as other than Recent.

5. None of the species collected by the author from the other shell beds is extinct, according to Mr. Singleton's identifications. The palaeontology of the shell beds was not, however, studied in detail.

6. The author agrees with Jutson that the uplift of the Kororoit Creek and Altona shell beds is of later date than that which caused the development of the high level terraces along the Moonee Ponds Creek and the Maribyrnong River.

The emergence is therefore regarded as Recent.

IV. Nature of the Emergence.

Differential elevation of Recent marine deposits has been noted at Portarlington, Duck Ponds Creek, and between Sorrento and Dromana, indicating that, at least in part, the emergence was due to tectonic movements of uplift.

Evidence of Recent emergence is so common along the Victorian coast, however, that a eustatic fall of sea level may be suspected of having contributed to it. Such Recent emergence has been described by others, or has been observed by the author at Marlo, the Ninety Mile Beach, Waratah Bay, Cape Patterson, Port Phillip Bay, Apollo Bay, Warrnambool, and Portland. Proof that eustatic movements have occurred must, however, await further detailed studies in Victoria and in other States.

V. Acknowledgments.

The author is indebted to Dr. H. S. Summers for information concerning the Altona and Point Lonsdale districts, to Mr. F. A. Singleton and Mr. G. Mack for determination of fossils, to Mr. H. B. Hauser and Mr. G. Baker for assistance in levelling, and to Mr. J. S. Mann for help in regard to photography. Topographic information was kindly made available by the Secretary of the Air Board, and by officers of the Lands Department and the State Rivers and Water Supply Commission. The Altona ridges were partially mapped by Miss E. Mann, Mr. N. L. Spielvogel, and Mr. J. M. Carey, under the direction of the author.

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Fig. 1

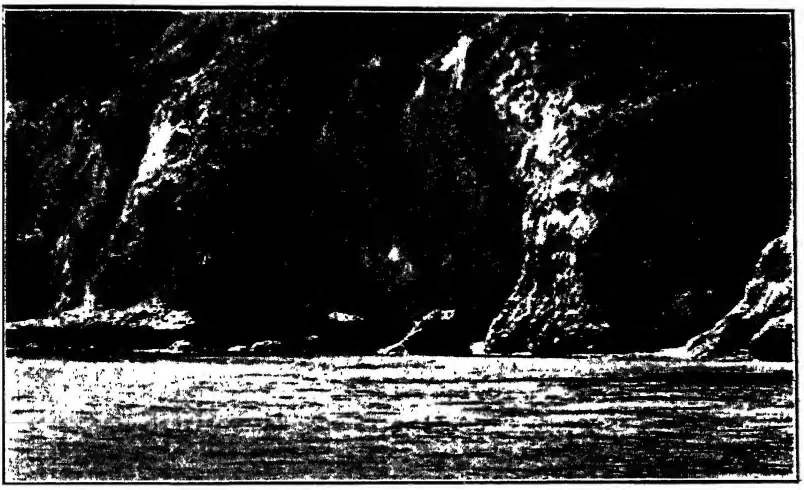

Fig. 2.

Fig. 3.

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Fig. 1.

Fig. 2.

Fig. 3.

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Explanation of Plates.

PLATE III.

FIG. 1.—Raised abrasion platform in granite, overlain by pebbles and talus, Oliver's Hill, Frankston.

FIG. 2.—Raised shore platform in granite, Dromana Bay.

FIG. 3.—Raised abrasion platform and pebble bed covered with aboriginal kitchen midden. Note vegetated cliff in background. Between Grice's Creek and Davey Point.

PLATE IV.

FIG. 1.—The cemented band in Pleistocene calcareous dune-rock, Point McArthur, Portsea.

FIG. 2.—Raised beach deposits showing normal stratification (in the excavation) overlain by calcareous dune sands. The remains of a fossil bird were obtained from the latter in the small upper excavation. West of Canterbury jetty, Rye.

FIG. 3.—Raised abrasion platform in Tertiary sandstone, overlain by pebbles. Fisherman's Point. Mornington.

[Proc. Roy. Soc. Victoria, 52 (N.S.), Pt. I., 1940.]

Art. V.—*A New Trilobite from Cootamundra, N.S.W.*

By EDMUND D. GILL, B.A., B.D.

[Read 8th June, 1939; issued separately, 1st March, 1940.]

The purpose of this paper is to record Upper Silurian sediments at Cootamundra, New South Wales, and to describe a new trilobite which is a characteristic member of the fauna. Mr. W. E. Williams of Cootamundra has sent to the National Museum, Melbourne, a collection of fossils and some rock specimens from this area. I wish to thank him for also making available his geological sketch-map and notes, from which the following stratigraphical data have been compended. The strata strike approximately north and south, being bounded by porphyry hills in the west, and schistose hills in the east. Pitch causes conglomerates and grits to outcrop in the north, forming Bandangan Hill. The Cootamundra fauna is preserved in fine-grained shales, and the following is a provisional faunal list:—

PLANTAE	*Fragmenta indeterminata* comparable with those in the Victorian Yeringian of Lilydale and district.
ANTHOZOA	Tabulate coral, indet.
CRINOIDEA	Crinoid joints, indet.
POLYZOA	Branching form.
BRACHIOPODA	*Atrypa reticularis* (Linnaeus).
	Atrypa aff. *scotica* (McCoy).
	Camarotoechia sp.
	Dalmanella aff. *elegantula* (Dalman).
	Lingula sp.
	Rhipidomella aff. *oblata* (Hall).
	Spirifer sp.
	Stropheodonta sp.
PELECYPODA	*Cypricardinia* sp.
	Leiopteria sp.
	Palaeoneilo aff. *spectabilis* Chapman.
	Palaeosolen sp.
	Paracyclas aff. *lirata* Hall.
	Pterinea sp.
GASTEROPODA	*Loxonema* sp.
	Pleurotomaria sp.
PTEROPODA	*Tentaculites* aff. *tenuis* Sowerby.
TRILOBITA	*Calymene* (*Gravicalymene*) *cootamundrensis*, sp. nov.

CALYMENIDAE, H. Milne Edwards, 1840.

Calymene, Brongniart, 1822. Gravicalymene, Shirley, 1936.

GENOTYPE: *Gravicalymene convolva* Shirley.

CALYMENE (*Gravicalymene*) *cootamundrensis*, sp. nov.

CARAPACE:—Small, elongate, sub-ovate, widest across posterior of cephalon and tapering to posterior end of pygidium.

CEPHALON:—Sub-quadrilateral, approximately one-quarter of total length of carapace. Moderately convex. (See fig. 2.) Surface ornamented with tubercles of varying sizes. The mould shows that the larger tubercles, at any rate, are perforated in their apices by canals which apparently connect the exterior with the interior of the test. Glabella bell-shaped in outline, and standing well above the fixed cheeks; does not overhang preglabellar field; anterior border extends a little beyond the anterior border of the fixed cheeks. Three distinct lobes on each side, reducing in size posterior-anteriorly. First and largest lobes rounded-quadrilateral, with furrows deep and directed obliquely backwards. Second lobes rounded with their long diameter transverse; much smaller than first lobes but bigger than third. Second furrows deep, running almost straight in from axial furrows. Third lobes distinct and of rounded shape. Third furrows short and not so deep as others. Incipient fourth lobes present. Axial furrows deep and wide; contracted at the base. The "antennary pits" are placed outside the fourth lobes on each side in the axial furrows. Preglabellar field recurved with roll-like edge, which thins away at its ends. Fixed cheeks convex. Eyes anterior to second lobes, and nearer lateral margin of cephalon than axial furrow. Free cheek suture follows lateral border of cephalon very closely then swings in a fairly sharp curve to eye. From the eye the suture proceeds practically straight forward to anterior border of cephalon. (The nature of the suture was determined from material collected after the line-block of the whole trilobite was made.) Genal angles truncated so that the lateral border forms almost a right angle with the posterior border of the cephalon. Posterior intra-marginal furrows broad; the posterior walls are steeper than the anterior. The corresponding marginal ridge is grooved for about one-third of its length at the glabellar end on the interior surface (as shown by the internal cast). Occipital groove much narrower, longitudinally, than intramarginal furrows. Occipital ring narrows at the extremities, which turn in towards the corners of the fixed cheeks.

THORAX:—Consists of twelve or thirteen segments. Type incomplete, preserving ten whole pleurae and part of eleventh and twelfth. Axis approximately semi-circular in cross-section,

and about one-third of width of thorax; tapers posteriorly to accommodate itself to the narrower pygidial axis. Axal furrows deep. Axal rings and pleurae strongly grooved. Axal knobs fairly conspicuous. The pleurae run horizontally out from the axis to the fulcra, and then bend down vertically. The fulcra are situated half-way along the length of the pleurae.

PYGIDIUM—Convex, with drawn-bow outline. The axis is approximately semi-circular in cross-section and covers almost the full length of the pygidium. There are six axal annulations and four prominent lateral ribs grooved distally half their length. In addition there is on each side of the axis at the posterior end a very short ungrooved rib.

Measurements of specimens:—

(1) Holotype cephalon—	
Width across base	15 mm.
Length (minus preglabellar field) ..	6 mm.
(2) Paratype thorax-pygidium—	
Greatest width of thorax	12 mm.
Length of thorax (incomplete) ..	15 mm.
Greatest width of pygidium	8 mm.
Length of pygidium	5 mm.
(3) Paratype cephalon (right side incomplete)—	
Width from left genal angle to centre of glabella	7.5 mm.
Length of cephalon	7.5 mm.

Matrix:—Yellow to brown fine-grained shale.

Occurrence:—Oak's Creek, Cootamundra, N.S.W.

Horizon:—Upper Silurian.

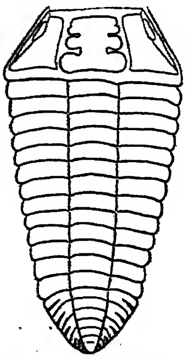

FIG. 1.—Diagram-restoration indicating the general proportions of *Calymene* (*Gravicalymene*) *cootamundrensis*, sp. nov. × 2 approx.

FIG. 2.—Profile of the cephalon of *Calymene* (*Gravicalymene*) *cootamundrensis*, sp. nov. × 4.

Observations:—The new species is not uncommon in the Cootamundra shales. As it is the only trilobite found in that locality, there is the greater confidence in concluding that the separated cephalon and thorax-pygidium presented as the types belong to the same species. Three cephala, two pygidia, and part of a thorax have been found associated on the same piece of shale $2\frac{1}{2}$ inches square.

Shirley, after describing the British species of Calymene (1931, 1933) presented a subdivision of the genus into nine genera (1936). Noting that the thorax and pygidium were relatively static, he concentrated on the cephalon and came to the conclusion that the variations of fundamental phylogenetic importance were:—

(1) The presence or absence of papillate lobes in the glabella with corresponding buttresses on the fixed cheeks.

(2) The plain, ridged, or roll-like character of the preglabellar field.

Principally by means of these criteria Shirley established his new genera. The genus Gravicalymene is characterized by the absence of papillate lobes and buttresses, and the presence of a roll-like edge in the preglabellar field. In describing fossils from the Baton River beds, New Zealand, Shirley (1938) referred *Calymene angustior* Chapman, a Victorian Yeringian form, to his new genus Gravicalymene. As far as the author is aware, *Gravicalymene cootamundrensis*, sp. nov., is only the third species to be referred to this new genus. The absence of the papilla-buttress structure is a feature confined to the Ordovician forms of " Calymene " in Britain and Scandinavia, but rare occurrences in the Silurian are known from America and Bohemia, (*C. celebra* Raymond and *C. baylei* Barrande). *G. convolva* Shirley belongs to the British Bala, but *G. angustior* (Chapman) and *G. cootamundrensis,* sp. nov., appear in the Australian Upper Silurian, and *G.* cf. *angustior* occurs in the New Zealand Lower Devonian.

Affinities:—*G. cootamundrensis* is nearest *G. angustior* (Chapman), (Chapman, 1915; Shirley, 1938, p. 487, cf. Etheridge and Mitchell, 1917.). They share such important features as the position of the eyes anterior to the second lobes (a rare character, according to Shirley), and the presence of an incipient fourth lobe. However, the new species is only about half the size of *G. angustior,* and as the fossils associated with *G. cootamundrensis* do not show abnormality in size, the difference cannot be environmental. Also the new species is much more elongate, and the quadrilateral cephalon with its narrow free cheeks are distinguishing features. The cephalon of the new species is

much flatter than that of the compared species. *G. cootamundrensis* has similar proportions to some specimens of *Calymene niagarensis* Hall (1843), which, although it is a papillate form (according to Shirley, but not shown in the figure quoted), has a roll-like preglabellar field like Gravicalymene. The quadrilateral cephalon and narrow free cheeks conspicuously mark off the new species.

Acknowledgment.

I wish to thank Mr. D. J. Mahony, M.Sc., director of the National Museum, Melbourne, for the study facilities provided for me in that institution. Also, I am grateful to Mr. L. A. Baillôt of the Melbourne Technical College for expert assistance with the photography.

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Description of Plate.

(1) Thorax and pygidium (Paratype) of *Calymene* (*Gravicalymene*) *cootamundrensis*, sp. nov. × 4 approx. (No. 14083.)

(2) Mould of cephalon (not No. 14084) showing ornament. × 4 approx. (No. 14085.)

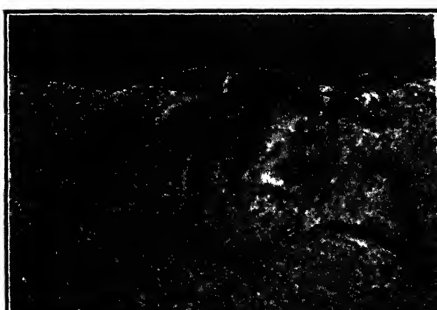
(3) Cast of cephalon (Holotype). × 4 approx. (No. 14084.)

(4) Cast of another cephalon showing outline and nature of preglabellar field (Paratype). × 4 approx. (No. 14086.)

The numbers in brackets are the registered numbers of the specimens in the National Museum, Melbourne.

1. 1.

2. 2.



3. 4.

[Proc. Roy. Soc. Victoria, 52 (N.S.), Pt. I., 1940.]

Art. VI.—*Observations on the Mineral and Vitamin Content of Australian Milk.*

By R. C. HUTCHINSON, B.Sc.

[From the Australian Institute of Anatomy, Canberra.]

[Read 13th July, 1939; issued separately, 1st March, 1940.]

Introduction.

The vitamin content of cow's milk has been shown to vary within reasonably wide limits, while it is well known that the mineral content, although remarkably constant, also varies within what might be termed physiological limits. During the routine analysis of a number of sweetened and unsweetened condensed milk samples from various parts of the world, Professor J. L. Rosedale, of the King Edward VII. College of Medicine in Singapore, found that the Australian samples were low in vitamin A. In a private communication he suggested that an explanation of the difference may be found in the reputedly low phosphorus content of Australian soils, and some support was given to this hypothesis by Richmond's (1930) suggestion that lecithin, because of its phosphorus content, may be an index of the vitamin (presumably vitamin A) content of butter-fat. Initially, the object of this investigation was to investigate Professor Rosedale's hypothesis and in so doing to determine the vitamin A content of a large number of Australian milk samples. Later, however, it was decided to extend the investigation with the object of discovering any correlations which might exist between the major vitamin and mineral constituents of milk.

One hundred and sixty-eight samples of mixed milk, representing the milk from 6,460 cows, were collected over a period of twelve months from New South Wales, Victoria and Tasmania. One hundred and twenty-five samples were known to be from afternoon milkings. The mineral constituents estimated were:—calcium, phosphorus, potassium, sodium, magnesium, sulphur, and iron. The vitamins estimated were:—vitamin A and carotene, vitamin B_1 (thiamin), vitamin B_2 (riboflavin), and vitamin C. The last named was estimated in each sample within twelve hours of collection and the milk was only exposed to direct daylight at the time of collection and while the estimation was being carried out in the laboratory. The methods employed for the estimation of the vitamin constituents were chosen because they involved the minimum amount of time and gave results, the relative values of which were reliable. But because the methods employed were non-biological the results are considered comparative only, although during preliminary work results obtained by these methods were checked against results obtained by well-controlled biological methods for the same samples and, so far as the results could be compared, they were in good agreement.

Methods of Analysis.

Fat was estimated by Richmond's (1930) modification of the Roese Gottlieb method. The specific gravity was determined with a Westphal balance and corrected for temperature.

VITAMIN A AND CAROTENE.

A pint of milk was centrifuged, the skim milk separated and kept for later determinations, the cream churned into butter, portion of the butter dissolved in petroleum ether and the whole transferred to a separating funnel containing distilled water. The ethereal layer was separated, washed and evaporated under suction at about 30°C. Because facilities were not available for estimating carotene spectro-photometrically, it was estimated in the warm residual butter-fat by a modification of Palmer's (1922) colorimetric method. Several workers have found that for butter-fat the graph given by Palmer gives carotene values which are several times too high, and Barnett (1934) has obtained a correction factor .28 which enables more accurate results to be obtained. However, Barnett assumes that carotene is the only colouring matter of consequence in butter-fat, but Gillam (1934) has shown that the ratio of carotene to xanthophyll in English butter-fat is fairly constant, being approximately 14:1 by weight, and has estimated the carotene value at approximately 94 per cent. of the total yellow colour of the butter-fat. This result is supported by the work of Baumann and Steenbock (1933) on an American butter-fat. Hence a more accurate conversion factor would be .263. Introducing this modification and simplifying Palmer's expression we have:—

$$\text{Percentage carotene} = \frac{.00268 \times .263 \times K_2Cr_2O_7 \text{ equivalent}}{\text{Depth of butter-fat}}$$

$$= \frac{\text{Reading on } x \text{ axis in fig. I}}{\text{Depth of butter-fat}}$$

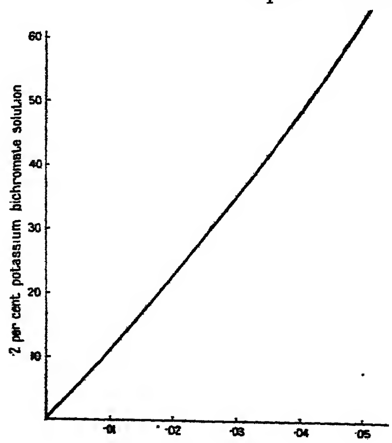


FIG. 1.

To estimate vitamin A, 2 gms. of butter-fat were saponified with 15 cc. of N/2 alcoholic potassium hydroxide, 20 ccs. of water added, the whole transferred to a separating funnel and extracted with two quantities of 25 ccs. of ether. The ethereal extracts were washed with water, then with N/2 aqueous potassium hydroxide and again with water, after which the ether was evaporated under suction at about 30°C. The residue was dissolved in purified ethyl alcohol, made up to 10 ccs. and vitamin A estimated in the solution with a Hilger Vitameter A using the factor 1600.

VITAMIN B_1.

In 1935, Schopfer published a paper showing that vitamin B_1 is a growth factor for the mould *Phycomyces blakesleeanus*, and he outlined a method for the estimation of vitamin B_1. It was later found (Robbins and Kavanagh (1937), Sinclair (1937), Schopfer and Jung (1937)) that both vitamin B_1 and its degradation products promote the growth of the mould. Hence the method about to be described for the estimation of vitamin B_1 actually estimates vitamin B_1 and any of its breakdown products which might be present in fresh milk.

Into 50 cc. Erlenmeyer flasks were placed 0.2 cc. of skim milk, each milk sample to be analysed, being done in triplicate. Skim milk was used, for otherwise a thin layer of butter-fat settled on the surface of the media and the slight anaerobic conditions thus introduced inhibited the growth of the mould. To each flask was then added 10 ccs. of a medium consisting of:—

Glucose	166.8	gms.
Asparagin	6.4	,,
$MgSO_4 + 7H_2O$	0.84	,,
KH_2PO_4	2.5	,,
H_2O	1,665	ccs.

and the pH was adjusted to approximately 6.6 by the addition of one or two drops of dilute sodium hydroxide.

A standard range was also set up containing 10 ccs. of media as before, but in place of milk the following amounts of vitamin B_1 were added:—0.5, 0.4, 0.3, 0.2, 0.1, 0.01, 0.001 international units. These flasks were set up in duplicate and all the flasks then plugged and sterilized at 107°C. for 10 minutes. A culture of *Phycomyces blakesleeanus* was prepared a fortnight previously in 100 ccs. of Wort Agar, made as follows:—25 ccs. of malt extract, 4 gms. of agar, and 200 ccs. of water were made up and autoclaved at 110°C. for 15 minutes. Several grams of the spore bearing mycelium were removed with sterile forceps and thoroughly washed in sterile water contained in a beaker covered with a watch glass. Each flask was then inoculated with two drops (about 0.2 cc.) of the spore bearing suspension

by means of a sterile pipette. The suspension was stirred frequently to ensure that the spores did not sediment. The inoculated flasks were then left in the dark at room temperature (22°C.) for ten days. All the mycelia were then removed, washed in running water, alcohol, and ether, rolled into small balls, dried in a hot air oven at 110°C. and then weighed.

From the weights of the mycelia in the standard flasks, a graph, of which Fig. II. is typical, was drawn, and from this graph the amounts of vitamin B_1 in the other flasks calculated.

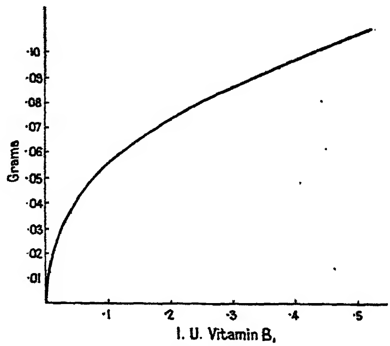


Fig. 2.

Vitamin B_2.

Was estimated in 100 ccs. of skim milk according to the second method described by Weisberg and Levin (1937). The aqueous solution of riboflavin contained much foreign matter, but this did not interfere with the estimation. The relation between the fluorescence intensity of sodium fluorescein (May and Baker Limited) and vitamin B_2 is given in Fig. III., which differs slightly from that given by Weisberg and Levin, for it is a straight line which does not pass through the origin.

Vitamin C.

To 10 ccs. of milk were added 10 ccs. of 20 per cent. trichloracetic acid; the solution was mixed well and then filtered. The precipitate was washed once with a little distilled water and the filtrate made up to 25 ccs. A burette was charged with this solution and it was added drop by drop to a standardized solution of 2:6 dichlorphenolindophenol until the red colour was just discharged. Knowing the strength of the dichlorphenolindophenol solution, the vitamin C present was determined.

Ashing.

300 ccs. of milk in a porcelain basin were dried on a water bath, a little alcohol being added to facilitate evaporation. When dry, the residue was heated over a bunsen to set the carbon and then placed in a muffle at a temperature of 400°–450°C. To

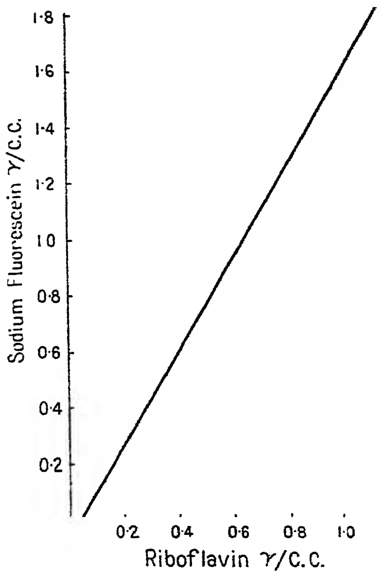


FIG. 3.

complete the incineration, the carbonized mass was cooled, mixed with water, dried, and returned to the muffle. The following determinations were carried out in duplicate on the ash which was dissolved in the minimum amount of hydrochloric acid and the volume made up to 100 ccs. :—

1. *Calcium.*—25 ccs. of the ash solution were made alkaline with ammonia and the resulting precipitate filtered off and washed. The filtrate and washings were kept for the sulphur determination. The precipitate was then dissolved in the minimum amount of hydrochloric acid, sodium acetate solution added and adjustment made to pH 5.0, using congo red as indicator. Calcium was then precipitated at 40°C. with an excess of saturated ammonium oxalate, the solution allowed to stand one hour, filtered, washed with water and a little dilute ammonia, incinerated and weighed as CaO.

2. *Magnesium.*—The combined filtrate and washings were evaporated to about 100 ccs., and 20 ccs. of nitric acid added. The beaker was covered, evaporated to dryness, 5 ccs. of hydrochloric acid were added, then evaporated almost to dryness and the residue dissolved in hot water. The magnesium was precipitated by the addition of 3 ccs. of a 10 per cent. solution of ammonium phosphate and sufficient ammonium hydroxide to make the solution slightly alkaline. The solution was stirred vigorously, allowed to stand 15 minutes, 15 ccs. of ammonium hydroxide added and the precipitation allowed to proceed over-

night. It was then filtered, washed with dilute ammonia, transferred to a crucible, dried, ignited, and weighed as $Mg_2P_2O_7$.

3. *Sulphur.*—The filtrate from the calcium estimation to which 10 ccs. of concentrated hydrochloric acid had been added was evaporated almost to dryness. It was then made up to 250 ccs., 5 ccs. of dilute hydrochloric acid added, and boiled. Some acidified 3 per cent. barium chloride was also boiled and 8 ccs. slowly added to the sulphate solution. It was left for an hour, filtered, washed, ignited, cooled, three drops of a mixture containing 1 cc. of alcohol and 2 ccs. of sulphuric acid added, incinerated and weighed as $BaSO_4$.

4. *Potassium.*—To the filtrate from the sulphate determination, barium hydroxide solution was added in slight excess and it was evaporated to about 50 ccs. Ammonium carbonate was added, the solution filtered into a porcelain dish, washed with hot water and evaporated to dryness. Moisture and ammonium chloride were driven off, 5 ccs. of hot water added, the solution filtered into a tared beaker, the residue washed, one drop of hydrochloric acid added, the filtrate evaporated to dryness and weighed as $NaCl + KCl$. 15 ccs. of 20 per cent. perchloric acid were added and it was evaporated almost to dryness. To the almost dry, cold residue 10 ccs. of a washing solution consisting of 1 cc. of 20 per cent. perchloric acid in 100 ccs. of 98 per cent. alcohol were added. The solution was stirred well, set aside for 5 minutes, decanted through a tared sintered glass crucible, placed on the steam bath to remove alcohol, dissolved in the minimum amount of hot water, evaporated, 10 ccs. of washing solution added, stirred, filtered, dried for one hour at 130°C. and weighed as $KClO_4$.

5. *Sodium* was calculated from the two above results by difference.

6. *Phosphorus.*—The original solution was again made up to 100 ccs. and to 15 ccs. a little methyl orange was added and the solution boiled to drive off carbon dioxide. The solution was neutralized with sodium hydroxide, 25 ccs. of 10 per cent. calcium chloride and a few drops of phenolphthalein added and the solution titrated with N/10 sodium hydroxide until a slight pink remained permanent after mixing. The percentage phosphorus was given by—

$$\frac{\text{cc. N/10 NaOH} \times .1551}{\text{weight of milk taken.}}$$

7. *Iron.*—To 35 ccs. of the remaining ash solution diluted to 100 ccs. were added 10 ccs. of concentrated hydrochloric acid. The iron was precipitated with 4 per cent. cupferron, filtered under suction, washed with water, dilute ammonia and again with water. The precipitate was transferred to an annealing cup, heated over a bunsen, incinerated and weighed directly as Fe_2O_3.

Results.

The results of the analyses are given in Tables I. and II.

TABLE I.—(MINERAL CONSTITUENTS.)

Number.	Specific Gravity.	Percentage Ca.	Percentage P.	Percentage K.	Percentage Na.	Percentage Mg.	Percentage S.	Percentage Fe.
1 ..	1·0315	·130	·082	·156	·044	·011	·009	·000090
2 ..	1·0320	·125	·088	·148	·042	·009	·010	·000108
3 ..	1·0310	·120	·086	·142	·042	·012	·009	·000072
4 ..	1·0332	·107	·087	·134	·048	·011	·008	·000081
5 ..	1·0331	·134	·090	·145	·051	·009	·013	·000126
6 ..	1·0330	·118	·097	·148	·050	·013	·008	·000081
7 ..	1·0321	·122	·094	·142	·049	·014	·008	..
8 ..	1·0325	·111	·090	·138	·051	·011	·007	..
9 ..	1·0320	·120	·086	·140	·057	·010	·008	·000108
10 ..	1·0317	·118	·075	·145	·054	·013	·008	·000108
11 ..	1·0315	·125	·091	·152	·045	·014	·010	·000065
12 ..	1·0317	·128	·086	·150	·040	·012	·010	·000073
13 ..	1·0310	·127	·078	·146	·042	·011	·011	·000068
14 ..	1·0315	·140	·084	·150	·045	·013	·016	·000084
15 ..	1·0311	·119	·080	·144	·047	·012	·009	·000104
16 ..	1·0320	·125	·085	·147	·050	·011	·009	·000070
17 ..	1·0311	·130	·084	·148	·045	·012	·010	·000081
18 ..	1·0310	·135	·087	·150	·050	·011	·012	·000210
19 ..	1·0311	·116	·079	·135	·058	·009	·009	·000089
20 ..	1·0312	·125	·087	·142	·053	·012	·009	·000090
21 ..	1·0310	·116	·082	·140	·048	·009	·008	·000075
22 ..	1·0316	·117	·083	·143	·050	·010	·009	·000080
23 ..	1·0315	·112	·080	·145	·049	·011	·008	·000099
24 ..	1·0311	·130	·084	·148	·051	·011	·010	·000088
25 ..	1·0305	·126	·080	·146	·040	·010	·009	·000074
26 ..	1·0314	·125	·079	·146	·043	·011	·007	·000081
27 ..	1·0311	·122	·075	·151	·041	·011	·008	·000086
28 ..	1·0311	·126	·081	·147	·042	·011	·009	·000109
29 ..	1·0310	·125	·079	·147	·049	·009	·009	·000079
30 ..	1·0310	·122	·079	·139	·045	·011	·008	·000063
31* ..	1·0317	·097	·082	·125	·046	·007	·007	·000062
32 ..	1·0304	·117	·077	·138	·060	·011	·008	·000084
33 ..	1·0304	·124	·075	·140	·055	·011	·009	·000088
34 ..	1·0313	·110	·078	·139	·048	·010	·009	·000078
35 ..	1·0307	·120	·082	·145	·049	·014	·009	·000090
36 ..	1·0312	·123	·080	·150	·045	·007	·009	·000067
37 ..	1·0305	·112	·082	·145	·041	·010	·008	·000080
38 ..	1·0314	·121	·070	·151	·042	·009	·008	..
39* ..	1·0303	·099	·076	·147	·045	·011	·008	·000092
40 ..	1·0312	·126	·075	·153	·046	·010	·010	·000105
41 ..	1·0314	·119	·081	·142	·047	·011	·008	·000096
42 ..	1·0304	·119	·076	·148	·050	·012	·008	·000065
43 ..	1·0319	·131	·082	·154	·046	·011	·010	..
44 ..	1·0314	·126	·078	·153	·053	·011	·009	·000101
45* ..	1·0300	·117	·080	·145	·040	·010	·008	·000068
46 ..	1·0310	·119	·081	·148	·050	·011	·009	·000067
47 ..	1·0315	·089	·074	·136	·051	·011	·009	·000067
48* ..	1·0319	·134	·092	·145	·048	·010	·012	·000070
49* ..	1·0310	·120	·078	·148	·047	·010	·009	..
50 ..	1·0299	·112	·077	·139	·050	·011	..	..
51 ..	1·0306	·125	·085	·151	·053	·013		..
52 ..	1·0313	·118	·080	·148	·048	·011	·009	..
53 ..	1·0298	·135	·079	·157	·058	·019	·012	..
54* ..	1·0320	·122	·088	·156	·050	·013	·009	..
55 ..	1·0323	·111	·081	·152	·046	·011	·007	..
56 ..	1·0320	·116	·080	·150	·051	·012	·009	..
57 ..	1·0301	·095	·079	·142	·041	·012	·008	..
58 ..	1·0300	·116	·080	·148	·040	·011	·009	..
59 ..	1·0298	·102	·080	·147	·042	·010	·008	..
60 ..	1·0316	·128	·086	·149	·041	·010	·009	..
61 ..	1·0306	·120	·081	·148	·040	·011	·009	..
62 ..	1·0313	·123	·078	·151	·042	·011	·009	..
63 ..	1·0316	·126	·080	·150	·041	·010	·008	..
64* ..	1·0318	·128	·088	·148	·055	·011	·012	..
65* ..	1·0316	·108	·080	·139	·052	·011	·009	..
66 ..	1·0324	·118	·089	·142	·049	·012	·009	..

TABLE I.—(MINERAL CONSTITUENTS)—*continued.*

Number.		Specific Gravity.	Per-centage Ca.	Per-centage P.	Per-centage K.	Per-centage Na.	Per-centage Mg.	Per-centage S.	Per-centage Fe.
67	..	1·0323	·110	·084	·144	·047	·009	·008	..
68*	..	1·0310	·131	·081	·152	·046	·011	·011	..
69*	..	1·0316	·114	·085	·148	·047	·011	·008	..
70*	..	1·0317	·135	·082	·154	·051	·016	·011	..
71*	..	1·0316	·119	·080	·148	·048	·011	·009	..
72	..	1·0295	·108	·080	·146	·044	·010	·009	..
73*	..	1·0300	·127	·086	·150	·042	·011	·009	..
74*	..	1·0308	·130	·088	·154	·048	·013	·011	..
75	..	1·0330	·111	·080	·148	·049	·011	·007	..
76	..	1·0317	·118	·082	·145	·050	·011	·007	..
77	..	1·0316	·125	·084	·148	·052	·010	·008	..
78	..	1·0333	·130	·081	·151	·051	·011	·010	..
79	..	1·0321	·125	·080	·144	·056	·011	·009	..
80	..	1·0328	·121	·079	·143	·051	·011	·010	..
81	..	1·0320	·133	·080	·147	·049	·015	·010	..
82	..	1·0338	·121	·086	·143	·045	·013	·009	..
83	..	1·0316	·119	·082	·138	·051	·010	·009	..
84	..	1·0308	·122	·089	·127	·041	·011	·007	..
85	..	1·0307	·124	·078	·130	·039	·010	·008	..
86	..	1·0321	·099	·080	·119	·039	·009	·006	..
87	..	1·0315	·122	·081	·134	·043	·011	·009	..
88	..	1·0309	·123	·084	..	..	·011	·006	..
89	..	1·0306	·127	·086	·130	·039	·010	·004	..
90	..	1·0310	·135	·088	..	..	..	..	..
91	..	1·0302	·129	·083	..	..	·012	·003	..
92*	..	1·0308	·120	·083	·140	·053	·011	·007	..
93*	..	1·0319	·124	·088	·152	·055	·012	·008	..
94	..	1·0308	·114	·080	·138	·054	·012	·007	..
95*	..	1·0319	·119	·089	·136	·045	·011	·007	..
96	..	1·0320	·130	·086	·143	·048	·011	·010	..
97	..	1·0315	·121	·085	·148	·045	·009	·011	..
98*	..	1·0313	·094	·074	·140	·044	·013	·009	..
99*	..	1·0311	·123	·081	·149	·052	·008	·010	..
100	..	1·0317	·124	·087	·156	·048	·011	·009	..
101	..	1·0318	·129	·088	·150	·050	·012	·009	..
102	..	1·0319	·127	·084	·146	·051	·010	·008	..
103	..	1·0321	·105	·084	·132	·047	·012	·007	..
104	..	1·0312	·122	·074	·138	·042	·011	·008	..
105	..	1·0309	·121	·078	·143	·052	·010	·008	..
106	..	1·0308	·129	·082	·146	·048	·011	·009	..
107	..	1·0317	·132	·078	·156	·046	·012	·009	..
108	..	1·0317	·129	·080	·153	·044	·011	·008	..
109	..	1·0312	·124	·079	·146	·045	·009	·008	..
110	..	1·0315	·129	·079	·150	·048	·012	·008	..
111	..	1·0314	·120	·082	·138	·055	·011	·007	..
112	..	1·0313	·114	·081	·142	·039	·013	·007	..
113	..	1·0319	·120	·072	·140	·048	·010	·012	..
114	..	1·0328	·135	·088	·154	·045	·013	·010	..
115	..	1·0319	·124	·079	·134	·050	·011	·009	..
116	..	1·0318	·134	·083	·138	·049	·011	·009	..
117	..	1·0314	·129	·085	·140	·050	·011	·012	..
118	..	1·0315	·114	·082	·128	·056	·011	·008	..
119	..	1·0312	·132	·082	·145	·052	·012	·011	..
120	..	1·0322	·130	·085	·142	·054	·014	·010	..
121	..	1·0312	·126	·075	·135	·045	·011	·010	..
122	..	1·0313	·124	·087	·138	·045	·013	·011	..
123	..	1·0324	·127	·086	·135	·046	·011	·009	..
124	..	1·0329	·121	·073	·138	·048	·009	·008	..
125	..	1·0318	·109	·076	·124	·048	·010	·008	..
126	..	1·0317	·116	·074	·130	·046	·010	·007	..
127	..	1·0314	·117	·080	·148	·047	·012	·010	..
128	..	1·0304	·112	·079	·145	·042	·009	·010	..
129	..	1·0311	·122	·084	·150	·048	·012	·009	..
130	..	1·0312	·119	·086	·146	·049	·011	·008	..
131	..	1·0324	·125	·078	·148	·052	·012	·007	..
132	..	1·0314	·102	·066	·138	·041	·013	·006	..
133	..	1·0309	·121	·085	·141	·050	·011	·008	..
134	..	1·0314	·120	·080	·140	·048	·011	·008	..
135	..	1·0309	·119	·079	·143	·046	·010	·010	..
136	..	1·0309	·114	·077	·141	·058	·011	·007	..
137	..	1·0325	·129	·077	·153	·056	·013	·009	..

TABLE I.—(MINERAL CONSTITUENTS)—*continued.*

Number.	Specific Gravity.	Percentage Ca.	Percentage P.	Percentage K.	Percentage Na.	Percentage Mg.	Percentage S.	Percentage Fe.
138 ..	1·0329	·121	·084	·149	·040	·011	·008	..
139 ..	1·0319	·105	·075	·147	·045	·008	·007	..
140 ..	1·0320	·114	·086	·148	·050	·012	·008	..
141 ..	1·0316	·094	·078	·119	·045	·011	·007	..
142 ..	1·0313	·118	·074	·134	·048	·010	·012	..
143 ..	1·0318	·097	·078	·145	·050	·008	·009	..
144 ..	1·0311	·110	·082	·132	·038	·009	·009	..
145 ..	1·0323	·118	·078	·131	·056	·011	·010	..
146 ..	1·0320	·119	·082	·187	·052	·010	·012	..
147 ..	1·0317	·108	·089	·141	·054	·010	·008	..
148 ..	1·0301	·140	·085	·158	·059	·011	·009	..
149 ..	1·0308	·126	·083	·153	·050	·011	·008	..
150 ..	1·0300	·123	·082	·151	·042	·012	·007	..
151 ..	1·0326	·125	·089	·147	·046	·011	·008	..
152 ..	1·0323	·117	·084	·148	·050	·012	·007	..
153 ..	1·0326	·110	·080	·144	·048	·011	·010	..
154 ..	1·0318	·095	·071	·135	·049	·010	·010	..
155 ..	1·0313	·112	·078	·132	·042	·011	·009	..
156 ..	1·0310	·121	·081	·134	·048	·011	·010	..
157 ..	1·0309	·131	·087	·147	·042	·011	·011	..
158 ..	1·0317	·133	·078	·146	·050	·014	·012	..
159 ..	1·0312	·121	·078	·142	·053	·010	·009	..
160 ..	1·0321	·125	·080	·150	·044	·011	·008	..
161 ..	1·0315	·114	·076	·141	·046	·011	·009	..
162 ..	1·0316	·126	·079	·138	·048	·012	·010	..
163 ..	1·0315	·128	·078	·154	·052	·011	·009	..
164 ..	1·0315	·119	·089	·150	·054	..	·008	..
165 ..	1·0311	·135	·079	·157	·056	·011	·014	..
166 ..	1·0318	·116	·078	·148	·048	·011	·009	..
167 ..	1·0311	·129	·082	·145	·046	·011	·010	..
168 ..	1·0316	·120	·081	·139	·048	·011	·009	..
Mean ..	1·0318†	·120	·082	·144	·048	·012	·009	·000087

† See text.

TABLE I.—(VITAMIN CONSTITUENTS.)

Number.	Percentage Fat.	Percentage Carotene in B.F.	I.U. Vitamin A /gm. B.F.	I.U. Vitamin B_1 /100 ccs.	Mgms. Vitamin B_2 /100 ccs.	Percentage Vitamin C.
1 ..	4·37	·00082	51	19	·22	·00260
2 ..	4·53	·00036	48	25	·17	·00226
3 ..	4·55	·00070	48	17	·12	·00080
4 ..	4·95	·00048	54	20	·22	·00034
5 ..	4·14	·00060	53	24	·17	·00044
6 ..	3·95	·00105	35	22	·16	·00036
7 ..	4·75	·00059	33	20	·18	·00074
8 ..	5·35	·00076	35	15	·12	·00186
9 ..	3·20	·00029	40	20	·12	·00046
10 ..	4·25	·00062	41	18	·17	·00200
11 ..	4·15	·00071	68	20	·16	·00048
12 ..	5·55	·00110	52	15	·15	·00180
13 ..	5·20	·00054	54	19	·19	·00250
14 ..	5·15	·00125	56	10	·17	·00178
15 ..	5·05	·00136	29	20	·19	·00079
16 ..	4·43	·00096	57	21	·20	·00087
17 ..	6·20	·00238	54	19	·12	·00128
18 ..	5·10	·00119	44	19	·16	·00230
19 ..	4·78	·00110	35	18	·17	·00198
20 ..	4·40	·00065	36	20	·15	·00290
21 ..	4·10	·00031	33	17	·14	·00052
22 ..	4·37	·00078	34	24	·12	·00248
23 ..	5·62	·00102	28	14	·16	·00032
24 ..	5·40	·00068	36	14	·15	·00094
25 ..	4·60	·00085	40	20	·20	·00224
26 ..	4·25	·00096	50	18	·14	·00108

TABLE I.—(VITAMIN CONSTITUENTS)—*continued.*

Number.	Percentage Fat.	Percentage Carotene in B.F.	I.U. Vitamin A /gm. B.F.	I.U. Vitamin B_1 /100 ccs.	Mgms. Vitamin B_2 /100 ccs.	Percentage Vitamin C.
27 ..	4·10	·00075	66	15	·22	·00056
28 ..	5·22	·00062	61	22	·16	·00224
29 ..	4·65	·00059	29	18	·15	·00240
30 ..	4·48	·00046	31	19	·14	·00054
31 ..	4·05	·00031	58	10	·18	·00032
32 ..	5·45	·00112	67	19	·17	·00044
33 ..	5·10	·00107	62	17	·16	·00034
34 ..	5·05	·00113	46	20	·17	·00034
35 ..	5·05	·00155	61	19	·15	·00050
36 ..	4·23	·00036	53	19	·19	·00032
37 ..	6·10	·00204	38	18	·18	·00048
38 ..	5·10	·00118	45	25	·16	·00258
39 ..	4·58	·00075	38	20	·18	·00303
40 ..	3·92	·00084	45	20	·12	·00240
41 ..	4·67	·00112	56	24	·15	·00172
42 ..	4·30	·00058	55	18	·19	·00192
43 ..	4·00	·00084	66	19	·16	·00206
44 ..	4·47	·00078	50	22	·21	·00192
45 ..	5·52	·00153	60	15	·19	·00048
46 ..	5·30	·00062	36	18	·21	·00254
47 ..	4·20	·00070	40	15	·16	·00224
48 ..	4·50	·00093	40	21	·18	·00192
49 ..	4·15	·00103	45	14	·17	·00234
50 ..	4·00	·00142	33	14	·21	·00172
51 ..	5·12	·00094	37	15	·16	·00238
52 ..	4·55	·00090	34	18	·21	·00168
53 ..	4·18	·00189	41	17	·12	·00188
54 ..	3·98	·00088	56	19	·21	·00184
55 ..	4·45	·00133	57	17	·26	·00220
56 ..	3·85	·00145	68	19	·18	·00160
57 ..	4·93	·00148	74	17	·22	·00046
58 ..	4·65	·00078	52	19	·17	·00192
59 ..	4·75	·00115	54	15	·16	·00101
60 ..	4·90	·00138	63	19	·25	·00186
61 ..	5·62	·00165	70	17	·21	·00238
62 ..	3·65	·00109	60	18	·17	·00182
63 ..	3·50	·00158	62	20	·12	·00196
64 ..	4·05	·00045	59	19	·22	·00192
65 ..	3·95	·00150	66	18	·24	·00190
66 ..	5·00	·00116	56	15	·12	·00224
67 ..	4·50	·00148	51	18	·18	·00122
68 ..	4·70	·00148	55	19	·19	·00184
69 ..	5·15	·00206	72	15	·22	·00252
70 ..	4·90	·00228	44	18	·23	·00182
71 ..	5·73	·00058	38	25	·17	·00184
72 ..	4·80	·00190	52	21	·18	·00162
73 ..	6·75	·00119	55	20	·19	·00240
74 ..	6·00	·00228	40	14	·22	·00123
75 ..	3·80	·00107	33	20	·17	·00250
76 ..	4·55	·00125	45	24	·12	·00222
77 ..	3·60	·00119	36	18	·18	·00062
78 ..	3·43	·00141	49	14	·18	·00108
79 ..	3·15	·00138	39	15	·13	·00188
80 ..	4·00	·00145	35	18	·18	·00092
81 ..	3·40	·00174	67	14	·20	·00156
82 ..	5·30	·00242	45	17	·19	·00120
83 ..	3·83	·00135	38	19	·17	·00098
84 ..	3·95	·00070	33	17	·12	·00250
85 ..	3·80	·00183	37	20	·12	·00222
86 ..	3·45	·00098	40	21	·14	·00148
87 ..	4·25	·00135	47	19	·20	·00260
88 ..	3·85	·00111	29	17	·09	·00306
89 ..	3·65	·00167	34	19	·17	·00150
90 ..	3·70	·00060	35	19	·18	·00054
91 ..	3·90	·00245	33	20	·27	·00044
92 ..	5·00	·00090	46	..	·17	·00096
93 ..	4·60	·00078	46	24	·17	·00084
94 ..	4·40	·00081	36	19	·18	·00093
95 ..	5·15	·00101	45	16	·17	·00139
96 ..	..	·00098	47	19	·20	·00200
97 ..	..	·00105	63	18	·19	·00098
98 ..	4·12	·00065	52	20	·16	·00192

TABLE I.—(VITAMIN CONSTITUENTS)—*continued.*

Number.	Percentage Fat.	Percentage Carotene in B.F.	I.U. Vitamin A /gm. B.F.	I.U. Vitamin B_1 /100 ccs.	Mgms. Vitamin B_2 /100 ccs.	Percentage Vitamin C.
99 ..	3·98	·00058	44	25	·13	·00128
100 ..	..	·00049	29	20	·16	·00130
101 ..	4·33	·00155	56	18	·17	·00084
102 ..	5·34	·00134	44	24	·14	·00238
103 ..	4·88	·00221	54	19	·16	·00156
104 ..	4·28	·00190	57	23	·20	·00044
105 ..	4·27	·00105	33	18	·12	·00036
106 ..	4·63	·00045	34	15	·19	·00172
107 ..	4·35	·00056	35	28	·16	·00068
108 ..	4·85	·00095	28	20	·13	·00034
109 ..	4·04	·00060	36	18	·17	·00036
110 ..	3·85	·00058	36	18	·15	·00206
111 ..	4·65	·00060	40	15	·19	·00044
112 ..	5·25	·00161	68	19	·30	·00042
113 ..	3·10	·00172	61	21	·12	·00302
114 ..	4·15	·00121	56	14	·15	·00117
115 ..	4·05	·00150	60	14	·15	·00192
116 ..	5·45	·00065	40	19	·16	·00151
117 ..	5·10	·00084	37	15	·18	.
118 ..	5·05	·00120	33	18	·17	·00192
119 ..	4·95	·00114	38	17	·17	·00166
120 ..	4·33	·00074	45	26	·17	·00086
121 ..	6·10	·00036	67	14	·20	·00268
122 ..	5·00	·00048	35	23	·16	·00192
123 ..	4·68	·00056	38	19	·18	·00258
124 ..	4·30	·00098	57	20	·28	·00136
125 ..	4·00	·00145	62	22	·17	·00248
126 ..	4·90	·00200	46	23	·18	·00220
127 ..	5·63	·00068	61	13	·15	·00068
128 ..	4·90	·00064	35	24	·19	·00232
129 ..	6·45	·00079	39	25	·22	·00240
130 ..	6·10	·00082	49	27	·20	·00168
131 ..	3·70	·00067	45	22	·16	·00210
132 ..	4·65	·00104	36	18	·16	·00254
133 ..	3·50	·00092	53	16	·15	·00224
134 ..	3·53	·00040	38	20	·14	·00322
135 ..	3·05	·00084	45	21	·17	..
136 ..	4·10	·00112	28	17	·19	..
137 ..	3·30	·00084	45	16	·18	..
138 ..	5·20	·00058	56	15	·23	..
139 ..	3·73	·00065	55	23	·16	..
140 ..	3·85	·00153	66	25	·15	..
141 ..	3·42	·00078	33	15	·17	..
142 ..	4·25	·00103	40	22	·17	..
143 ..	3·75	·00093	35	19	·29	..
144 ..	3·45	·00070	52	20	·22	..
145 ..	3·70	·00090	38	21	·23	..
146 ..	3·95	·00102	44	14	·15	..
147 ..	5·15	·00132	62	16	·22	..
148 ..	4·12	·00145	55	20	·17	..
149 ..	3·98	·00148	51	22	·18	..
150 ..	4·33	·00165	56	18	·15	..
151 ..	5·34	·00109	50	24	·19	..
152 ..	4·88	·00058	60	22	·14	..
153 ..	4·28	·00070	36	15	·19	..
154 ..	4·27	·00107	40	18	·17	..
155 ..	4·63	·00086	30	15	·17	..
156 ..	5·05	·00075	45	18	·18	..
157 ..	5·10	·00084	56	19	·22	..
158 ..	4·20	·00078	66	25	·17	..
159 ..	4·75	·00068	59	15	·14	..
160 ..	3·90	·00070	62	11	·19	..
161 ..	4·10	·00090	60	18	·14	..
162 ..	4·00	·00135	60	20	·10	..
163 ..	4·65	·00111	63	25	·18	..
164 ..	5·20	·00167	54	21	·19	..
165 ..	4·85	·00063	62	20	·19	..
166 ..	3·90	·00065	51	14	·13	..
167 ..	4·20	·00058	65	19	·18	..
168 ..	4·06	·00079	43	20	·17	..
Mean ..	4·51	·00104	47·6	18·8	·17	·00156

General Discussion of Results.

In Table I. the mean specific gravity was not obtained by summing all the specific gravities and dividing by their number. To average specific gravities they should be first calculated to specific volumes, these averaged, and the average specific gravity deduced from the average specific volume. The average specific gravity then was calculated from the following:—

$$S.G. = \cfrac{1}{\cfrac{\frac{1}{1.0315} + \frac{1}{1.0320} + \frac{1}{1.0310} + \cdots + \frac{1}{1.0316}}{168}}$$

When the specific gravity and fat content of milk are known, the total solids and solids-not-fat may be readily calculated by means of Richmond's (1930) milk scale. The mean total solids and solids-not-fat content of the milk samples estimated in this manner are 13.50 and 8.99 per cent. respectively.

A slight direct correlation was found to exist between the solids-not-fat and phosphorus content of the samples, the Pearsonian coefficient of correlation being .40.

In Table III. the composition of milk from different breeds of cattle including the Australian Illawarra Shorthorn is compared. It will be seen that the composition of milk from Australian Illawarra Shorthorn herds resembles that from Ayrshire rather than Guernsey or Jersey herds. All samples were from afternoon milkings.

TABLE III.—COMPOSITION OF MILK FROM COWS OF DIFFERENT BREEDS.

Breed.	Number of Samples.	Total Solids Per Cent.			Fat Per Cent.			Solids-not-fat Per Cent.		
		Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
		%	%	%	%	%	%	%	%	%
Australian Illawarra Shorthorn	16	14·32	11·67	13·02	4·93	3·35	4·35	9·39	8·32	8·67
Ayrshire ..	12	14·10	11·94	13·18	5·05	3·50	4·43	9·05	8·44	8·75
Guernsey ..	4	14·81	14·36	14·56	5·45	5·30	5·37	9·36	9·06	9·19
Jersey ..	10	15·53	13·04	14·25	6·10	4·50	5·36	9·43	8·54	8·89

VITAMIN A AND CAROTENE.

Very few figures have been published on the vitamin A content of butter-fat which are comparable with those obtained during this investigation. In the large majority of cases the estimations have been carried out on butter-fat from a small number of cows, a particular breed of cow, or on butter-fat obtained during a

TABLE II.—FREQUENCY DISTRIBUTION OF RESULTS.

																					Mean																						
Specific Gravity	D.	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	..	..	..
	F.	1	0	0	2	1	4	2	1	1	4	2	3	2	6	6	11	11	9	8	9	12	11	11	7	8	8	5	1	4	3	2	2	0	2	3	2	1	2	1	..	..	..
Fat ..	D.	..	..	..	..	..	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·8	3·9	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9	6·0	6·1	6·2	6·3	6·4	6·5	< 6·6	..
	F.	..	..	..	..	..	2	2	1	3	5	1	6	4	8	13	11	8	13	6	6	8	8	5	9	5	11	8	5	2	3	4	1	0	0	1	3	1	0	0	1	1	..
Carotene ..	D.	..	..	..	..	..	..	..	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	156	162	168	174	180	186	192	198	-04	210	216	222	228	< 234
	F.	..	..	..	..	..	..	..	3	2	1	6	3	16	11	8	12	12	6	9	6	10	9	6	2	3	6	6	6	5	1	4	2	0	1	3	1	2	0	0	1	2	3
Vitamin A ..	D.	..	..	..	..	..	..	..	..	..	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	..	..	..	..	..	..	..	..	..
	F.	..	..	..	..	..	..	..	..	..	3	5	1	13	17	11	12	2	6	15	4	5	9	9	14	5	8	10	3	6	7	1	1	1	..	..	..	..	..	..	..	..	..
Vitamin B_1	D.	..	..	..	..	..	..	..	..	..	..	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	..	..	..	..	..	..	..	..	..	..	..	..	..
	F.	..	..	..	..	..	..	..	..	..	..	2	1	0	1	12	18	4	12	25	28	25	8	8	4	8	8	1	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..
Vitamin B_2	D.	..	..	..	..	..	..	..	..	..	..	..	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	..	..	..	..	..	..	..	..	..
	F.	..	..	..	..	..	..	..	..	..	..	..	1	1	0	14	4	9	14	20	31	21	18	8	6	11	3	1	1	1	1	1	1	1	..	..	..	..	..	..	..	..	..
Vitamin C ..	D.	..	..	..	..	36	44	52	60	68	76	84	92	100	108	116	124	132	140	148	156	164	172	180	188	196	204	212	220	228	236	244	252	260	268	276	284	292	300	308	316	324	..
	F.	..	..	..	..	10	8	7	2	2	2	5	3	4	2	1	3	3	2	3	1	3	5	4	8	11	4	1	4	7	5	4	8	5	1	0	0	1	2	1	0	1	..
Calcium ..	D.	< 100	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	..	..
	F.	9	2	0	0	2	0	1	3	1	4	3	5	0	7	0	6	5	7	11	10	10	8	5	7	12	8	5	4	8	7	3	2	2	3	6	0	0	0	0	2	..	..
Phosphorus ..	D.	..	..	..	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	..	..	..	..	..	..	..
	F.	..	..	..	1	0	0	0	1	1	1	1	5	6	4	4	17	14	23	12	16	5	11	8	11	6	8	6	2	1	2	0	1	0	0	1	..	..	..	..	..	..	..
Potassium ..	D.	< 126	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	..	..	..	..	..	..	..	..
	F.	4	0	1	1	0	3	1	3	0	5	4	2	1	11	5	8	4	9	6	4	12	9	9	21	3	12	6	4	5	5	0	4	2	1	..	..	..	..	..	..	..	..
Sodium ..	D.	..	..	..	..	..	..	..	..	..	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	..	..	..	..	..	..	..	..	..	..
	F.	..	..	..	..	..	..	..	..	..	1	4	6	7	13	2	5	15	12	7	22	10	18	10	8	5	5	5	4	1	3	1	1	..	..	..	..	..	..	..	..	..	..
Magnesium	D.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	07	08	09	10	11	12	13	14	15	16	17	18	19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	3	13	28	75	24	13	5	1	1	0	0	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sulphur ..	D.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	04	05	06	07	08	09	10	11	12	13	14	15	16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	0	4	20	43	53	24	8	9	1	1	0	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Iron ..	D.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	060	065	070	075	080	085	090	095	100	105	110	115	120	125	< 125	..	..	..	..	..	..	..	..	..	..	..	..	..
	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	6	5	3	8	3	7	1	2	2	4	0	0	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..

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particular season. Such results, obtained by spectrophotometric methods, have been published by Baumann et al. (1934), Beeson (1935), Booth et al. (1934), Gillam et al. (1936), Peterson et al. (1935), and Sutton and Kraus (1936). Sherman and Sherman (1937) give the mean vitamin A value of 86 samples of butter-fat as 50.60 ± 1.80 international units per gram, which differs only by three international units from the figure in Table I. Crawford et al. (1932) have determined the vitamin A activity of Australian butter-fat biologically, but because of the method used, the results are not directly comparable with those in this work. The frequency distribution table shows carotene to be a very variable constituent.

VITAMIN B_1.

Very few figures are to be found for the vitamin B_1 content of milk. Baker and Wright (1935) have published 23 international units per 100 ccs., which is four international units higher than the results obtained during this investigation, whilst Pyke (1937) found two samples contained 6 and 11 international units per 100 ml.

VITAMIN B_2.

Comparatively little work has been published on the vitamin B_2 content of milk. The figures .2 to .3 mgm. per 100 ccs., .1 mgm. per 100 ccs., and .176 to .26 mgm. per 100 ccs. have been obtained by Euler and Adler (1934), Kuhn et al. (1934), and Whitnah et al. (1937) respectively.

VITAMIN C.

The vitamin C content of milk has been investigated by many workers and appears to vary from $< .3$ (Levy and Fox, 1935) to 2.92 (Whitnah and Riddell, 1937) mgms. per 100 gms. 1.77 mgms. per 100 gms. which is slightly higher than the figure (1.56 mgms. per 100 gms.) given in Table I., is the mean of nineteen results obtained by Levy and Fox (1935), Whitnah and Riddell (1937), Ranganathan (1935), Fujita and Ebihara (1937), Meulemans and De Haas (1937), Rasmussen et al. (1936), Harris and Ray (1935), Correns (1937), Birch et al. (1933), Whitnah and Riddell (1936), Van Wijngaarden (1934), Kon and Watson (1937), Riddell et al. (1936), and Ferdinand (1936).

POTASSIUM, SODIUM, MAGNESIUM, AND SULPHUR.

Sherman (1936) gives .143 for the percentage of potassium in whole milk, Richmond (1930) .150, Crichton (1930) .168, and Trunz (1903) gives .136 and .149 per cent. For sodium Sherman gives .051 per cent., Richmond .037, Crichton .056, and Trunz gives .032 and .042 per cent. For the amount of magnesium in whole milk, Forbes et al. (1917) and Hart et al. (1909) each give .011 per cent., Sherman .012 per cent., Forbes et al. (1918) and Richmond .013 per cent., while Trunz gives

the range .011 to .015 per cent. and .012 to .017 per cent. König (1904) gives .007 per cent. as the amount of sulphur in whole milk which has been ashed. (Approximately 72 per cent. of the sulphur in milk is lost in ashing). These figures are in good agreement with those obtained during this survey.

IRON.

Table IV. gives the iron content of milk according to various investigators:—

TABLE IV.—IRON CONTENT OF MILK.

Investigator.	Parts per Million.	Investigator.	Parts per Million.
Anselm (1815)	·62– ·84	Lesne et al (1930)	·95
Davies (1931)	1·5–2·4	Langstein (1911)	·21–·49
Edelstein and Csonka (1912) ..	·28– ·49	Macfarlane (1932)	·48–·68
Elvehjem (1926)	·35– ·36	Nottbohm and Dorr (1914) ..	·21–·19
Fendler et al. (1914)	2·8–8·4	Sherman (1936)	2
Friedjung (1901)	·84–1·82	Soxhlet (1912)	·18–·84
König (1896)	·35–4·69	Trunz (1903)	·22–·36
		This Investigation	·87

These figures vary considerably, but the figure for Australian milk is well within the common range.

CALCIUM.

Table V. shows that the mean figure for the calcium content of Australian milk agreees very well with figures obtained by overseas investigators.

TABLE V.—CALCIUM AND PHOSPHORUS CONTENT OF MILK.

Investigator.	Percentage Ca.	Percentage P.
Bunge (1901)	..	·077–·084
Burr and Witt (1935)	·083–·141	·071–·117
Cranfield et al. (1927)	·132	·102
Crichton (1930)	·119	·100
Davies and Provan (1928)	·124	·105
Forbes et al. (1917)	·103	·078
Forbes et al. (1918)	·117	·094
Golding et al. (1932)	·128	·107
Hart et al. (1909)	·084–·097	·076
Hutchison (1906)	..	·096
Katagama (1908)	·119	·094
Katagama (1908)	·127	·098
König (1904)	·112	·080
Meigs et al. (1926)	·100	·087
Meigs et al. (1926)	·132	·114
Richmond (1930)	·109	·096
Sheehy (1921)	..	·090
Sherman (1936)	·118	·093
Sommer and Hart (1926)	·135	·095
Sommer and Hart (1926)	·124	·113
Sommer and Hart (1926)	·142	·102
Sommer and Hart (1926)	·129	·103
Trunz (1903)	·137	·083–·103
Trunz (1903)	·128	·089–·100
Wellmann (1937)	·118–·146	·096–·155
This Investigation	·120	·082

PHOSPHORUS.

Table V. compares the mean figure for the phosphorus content of Australian milk with twenty-five figures obtained by overseas investigators. It will be seen that three of the overseas figures are slightly lower and one practically equal to the Australian figure, whilst twenty-one are definitely higher. Hence it was considered reasonable to conclude that the phosphorus content of the Australian samples was low.

However, it was within the normal range according to Bunge, Burr and Witt, Wellman (see Table V.) and the following investigators. Sommer (1929) gives the range .068 to .119 per cent., Cranfield et al. (1927) (673 samples) .076 to .135 per cent., although 80 per cent. of the samples fell between the range .092 to .111 per cent., and Crichton (1930) has found it to be .073 to .127 per cent. for 220 samples.

It was at first thought that this low figure may be due to the method of estimation, but this was checked against the well-established method of titrating the ash solution with uranium acetate using potassium ferrocyanide as external indicator when both methods gave results in good agreement.

It has been recognized for some decades that many Australian soils, particularly the superficial soils, are deficient in phosphorus and this has been indirectly proved by the remarkable results which follow the use in New South Wales, Victoria, and Tasmania of phosphatic fertilizers. In an article by Cherry (1907) Victorian clay soils were compared with American clay soils, the clay soils being chosen because they contained a higher percentage of phosphorus than other soils. It was shown that Victorian clay soils contained 63 parts of phosphoric acid per 100,000 parts, whereas American clay soils contained 207 parts per 100,000. The Mallee soils were even lower, containing only 47 parts per 100,000.

During a survey conducted by Henry and Benjamin (1933), it was found that of 56 soils analysed from the southern coastal belt of New South Wales, only eight samples contained as much as five parts per 100,000 of citrate soluble phosphoric acid, the remaining 48 samples averaging 2.3 parts per 100,000.

Many other papers have been written containing data on the low phosphorus content of Australian soils. In the eastern States there is the work of Taylor and Hooper (1938), Taylor and England (1929), Taylor and Penman (1930), and Taylor et al. (1933), whilst in Western Australia there is the work of Hosking and Burvill (1938) and Teakle (1929).

In unpublished work carried out in this laboratory it was found, after analysing eighty-six samples of soil collected from dairy farms situated on the northern coastal belt of New South Wales, that each of these soils was very low in phosphorus.

Many research workers have found that the mineral content of pastures, fodder crops, cereals, &c., is related to the mineral content of the soils on which they are grown. In order to investigate this, one hundred and fifty-six samples of pastures and fodder crops were collected from the eighty-six previously mentioned dairy farms at the time the milk and soil samples were collected. The phosphorus content of these samples, dried at 100°C., was determined by a method similar to that used for milk, and the results together with comparative figures by overseas investigators are given in Table VI.

TABLE VI.—PHOSPHORUS CONTENT OF FEEDS.

Feed.	Remarks.	P Per Cent.	Number of Samples.	Country.	Authority.
Mixed pasture	From fertilized land	·149	11	Australia ..	This investigation
" "	From unimproved land	·178	46	" ..	" "
" "	Good pasture ..	·46	..	New Zealand	Rigg and Askew (1929)
" "	Poor hill pasture	·33	..	" "	" " "
" "	From both manured and unmanured land	·335	40	England ..	Armstrong (1907)
" "	From cultivated land	·32	24	England and Wales	Godden (1926)
" "	From hill country	·26	35	Scotland ..	" "
" "	From natural pasture	·29	22	" ..	Orr (1929)
" "	From cultivated land	·32	24	" ..	" "
" "	From poor hill country	·26	35	" ..	" "
" "	.. .. ..	·29	12	Kenya ..	Orr and Holm (1931)
" "	.. .. ..	·223	60	Mauritius ..	Lincoln (1937)
" "	Natural Pasture	·303	86	United States	Newlander et al (1933)
" "	" "	·19	96	" "	Archibald and Bennett (1933)
Fresh lucerne*	From fertilized land	·419	19	Australia ..	This investigation
" " *	From unimproved land	·411	33	" ..	" "
" " *	.. .. ..	·625	..	England ..	Woodman (1934)
" "	.. .. ..	·457	..	South Africa	Fox and Wilson (—)
Green oats ..	From fertilized land	·520	4	Australia ..	This investigation
" " ..	From unimproved land	·554	4	" ..	" "
Fresh sorghum	From fertilized land	·097	16	Australia ..	This investigation
" "	From unimproved land	·089	5	" ..	" "
Bran ..	.. .. ..	·98	5	Australia ..	This investigation
" ..	.. .. ..	1·32	..	America ..	Morrison (1936)
" ..	.. .. ..	1·20	..	Indiana ..	Purdue Uni. Agr. Exp. Sta. (1938)
" ..	.. .. .	1·452	..	Europe ..	Heubner and Reeb (1908)

* Pre-budding period.

From this table it was seen that the phosphorus content of these pastures and fodder crops was very low. In some cases it was lower in crops grown on fertilized land than in crops grown on unfertilized land. This throws doubt on the testimonies of the farmers who supplied the information regarding fertilization of these lands, although it is possible that soils on which these crops grew may have been so low in phosphorus that the amount of fertilizer used restored but little of the deficiency.

The mean phosphorus content of the mixed milk from these eighty-six dairy farms was .081 per cent. This does not differ appreciably from the mean figure given in Table I.

The question now arises as to whether the amount of phosphorus ingested by the cow determines the phosphorus content of milk. This question has been investigated by many workers and an excellent review of literature on the subject is included in a paper by Crichton (1930). On summing up the results of the various investigations a conclusion similar to that expressed by Forbes and Keith (1914) developed, namely, that the character of the feed may vary the phosphorus content of the milk, but only within normal limits.

Many of the milk samples collected during this survey were from herds which have been feeding for cow-generations on low phosphorus diets and often in localities where the conditions were so severe that cases of osteophagia were frequently observed (Henry and Benjamin, 1933). Where such conditions prevail, it seems reasonable to assume that this low phosphorus content of the milk can be due to no other cause than the low phosphorus content of Australian pastures and fodder crops, or indirectly to the low phosphorus content of Australian soils. This conclusion does not support that of Kincaid (1911), who analysed four milk samples from Victoria.

Correlations between the Vitamin and Mineral Constituents.

In a preliminary examination points were plotted for every value of each of the vitamins A, B_1, B_2, and C against the values for the mineral elements from the same milk sample. Twenty-eight graphs were thus obtained. These graphs were carefully examined, but in no instance could any correlation be detected between any two sets of results. Indeed, there was such a lack of correlation that it was considered unnecessary to apply any statistical treatment.

No correlation was found to exist between any of the vitamin and any of the mineral constituents of milk.

In view of the opinion expressed by Richmond (1930) that lecithin, because of its phosphorus content, may be an index of the vitamin content of milk, the lecithin content of thirty samples of milk was estimated by the method of Bordas and Raczkowski (1902) and the results examined as before, but again no correlation was detected. The mean figure for the lecithin content of these samples was .066 per cent.

A Correlation between the Phosphorus Content of Pasture and the Vitamin A Content of Milk.

Samples of feed as well as samples of milk were collected from most farms visited during this investigation, and during the examination of results, a most interesting correlation was found to exist between the phosphorus content of the pastures upon which certain herds grazed and the vitamin A content of the butter-fat from these herds.

On certain farms, which were comparatively large holdings, the herds were feeding on pasture alone. These farms (indicated by an asterisk in Table I.) were situated in the coastal dairying districts of New South Wales, the most southern being situated in the Richmond district and the majority of others in the Grafton district. According to information gathered from each farmer, these herds had been feeding in the same paddocks for several cow-generations, the pasture feed had never been supplemented with hand feed of any kind and the paddocks had never been artificially fertilized, so that the mineral and vitamin intake of these herds remained fairly constant throughout the year and from one year to another.

The specimens of pasture and milk were collected in late summer when pastures were poorest, but on each farm there was abundance of green grass on which the cattle could feed and, as will be seen later, the diet contained a large excess of carotene. The pasture samples, which were collected with the assistance of the farmers, were taken from many parts of the field and much care was taken to obtain a truly representative sample. The samples were not cut, but plucked by hand in order to simulate a cow's method of grazing, and herbage not eaten by the cow was not included in the sample. On most farms couch (*Cynodon* sp.) was the predominating grass, and on some farms this was the only pasture grass. Paspalum (*Paspalum* sp.) and various species of clover were also common, but native grasses other than couch constituted a very small portion of any pasture.

TABLE VII.

(Phosphorus and protein expressed as percentage of pasture dried at 100°*C.)*

I.U. Vitamin A /gm. of B.F.	Breed of Herd.	Percentage P in Pasture.	Percentage Protein in Pasture.	Carotene in Pasture mgms/kg.
58	Mixed	·217	10·12	180
38	"	·085	9·04	190
60	Jersey	·171	10·51	240
40	Mixed	·098	6·72	200
45	"	·133	6·56	200
56	"	·202	10·73	190
59	"	·186	9·05	180
66	"	·209	10·62	180
55	Jersey	·187	12·43	200
72	Mixed	·325	13·15	210
44	"	·101	10·20	250
38	"	·116	9·72	190
55	"	·169	9·54	190
40	Jersey	·147	10·89	200
46	Mixed	·096	9·05	200
46	"	·111	10·21	190
45	"	·186	12·20	180
52	Australian Illawarra Shorthorn	·132	8·45	200
44	Mixed	·124	8·35	180

Table VII. gives the amount of vitamin A per gram of butter-fat in the mixed milk from these herds and the percentages of phosphorus, protein, and carotene in the pastures upon which the herds were feeding. It will be seen that a direct correlation exists between the vitamin A content of the butter-fat and the phosphorus content of the pasture, the coefficient of correlation being .97.

The carotene content of the pastures was estimated by a method similar to that given by Bolin and Khalapur (1938) and it will be seen from Table VII. that the poorest pasture contained 180 mgms. of carotene per kilogram or approximately 288,000 international units of vitamin A per kilogram (Fixsen and Roscoe, 1937-38). According to the work of Fraps et al. (1937) and Guilbert and Hart (1935), cows on these pastures were receiving a large daily excess of vitamin A.

Hence it would appear that the vitamin A content of butter-fat is influenced in some way by the phosphorus as well as the carotene ingested by the cow as suggested by Professor Rosedale. However, there may be other underlying factors such as the stage of growth of the pasture, for it will be seen that there is also a considerable degree of correlation between the protein and phosphorus content of the pastures. Unfortunately, most of the milk samples were from mixed herds, and because of this the table loses some of its value. An interesting piece of confirmatory evidence is given by the following fact, however. The mean vitamin A content of five samples of mixed milk from cows feeding on pasture but receiving in addition a daily ration of bran (a rich source of phosphorus) was two international units higher than the mean figure for the results given in Table VII.

No similar correlation was found to exist between any of the other vitamins and the phosphorus or protein intake of the herd.

Summary.

Fat, vitamin A, carotene, vitamin B_1, vitamin B_2, vitamin C, calcium, phosphorus, potassium, sodium, magnesium, sulphur, and iron have been estimated in 168 samples of mixed milk. Methods and results have been presented. The mean results of all analyses appear in the following table:—

Specific gravity	1·0318	Calcium	·120 per cent.
Total solids	13·50 per cent.	Phosphorus	·082 per cent.
Solids-not-fat	8·99 per cent.	Lecithin	·066 per cent.
Fat	4·51 per cent.	Potassium	·144 per cent.
Carotene in Butter-Fat	·00104 per cent.	Sodium	·048 per cent.
Vitamin A in Butter-Fat	47·6 I.U./gm.	Magnesium	·012 per cent.
Vitamin B_1	18·8 I.U./100 ccs.	Sulphur	·009 per cent.
Vitamin B_2	·17 mgm/100 ccs.	Iron	·000087 per cent.
Vitamin C	·00156 per cent.		

By comparing the results with overseas figures it has been shown that the phosphorus content of the Australian milk, although within normal limits, was low. It has also been shown that no correlations exist between the vitamin and mineral constituents of milk. Subject to certain conditions, a correlation was discovered between the vitamin A content of butter-fat and the phosphorus content of the pasture.

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ART VII.—*Experiments on Manganese Deficiency Disease ("Grey Speck") of Cereals.*

By G. W. LEEPER, M.Sc.

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Introduction.

In a previous paper (2) the writer described some experiments on manganese deficiency (or "grey speck") disease of cereals. The present paper deals with further work on the same subject extending over five years. A short account is first given of the present state of knowledge with regard to this disease.

Many important crops are liable to this disease, including wheat, barley, and especially oats. The soils on which crops are affected—here called "deficient soils"—have a pH value of at least 6.5, usually over 7.0. The disease may be overcome by lowering the pH of the soil below 6.5, by adding a compound of manganese to the soil, or by spraying the affected plants with a solution of a manganese salt. Descriptions of the symptoms, various experiments in the field, and descriptions of some deficient soils are referred to in (2). Since deficient soils often contain normal quantities of total manganese, the deficiency must be due to a very low availability of that manganese.

It appears that the forms of manganese in the soil which take part in chemical reactions are firstly the bivalent ion, mostly attached to the colloids as exchangeable manganese; and secondly, higher oxides of manganese, which range from highly active to relatively inert forms. The only evidence as to the chemical composition of the higher oxides has been provided by Naftel (3) whose work favours the formula Mn_2O_3 which should probably therefore replace the former conventional formula MnO_2. The writer has suggested that this Mn_2O_3 may be divided into four fractions in order of activity according to arbitrary tests. The most reactive fraction (*a*) can oxidize the organic matter of the soil at pH 2; the next fraction (*b*) can oxidize quinol at pH 7; fraction (*c*) can oxidize hydrosulphite but not quinol at pH 7, while (*d*) is still less active. It was further suggested that plants can utilize only the bivalent ion and fractions (*a*) and (*b*) of Mn_2O_3. In neutral or alkaline soils if aeration is good, the bivalent ion is mostly changed into the higher oxides, and it appears that then the health of sensitive plants such as oats depends on the presence of appreciable quantities of manganic oxide in forms (*a*) and (*b*). Healthy alkaline soils contain over 100 parts per million of manganese

in this reactive form, while deficient soils have less than 25 parts. It appears that waterlogging, which has been successful in pot tests, cures the disease by reducing some of the manganic oxide to the bivalent state, after which it reverts under normal drainage to more reactive forms of manganic oxide; soluble manganese compounds when added to deficient soil are transformed into reactive forms of manganic oxide and so may remain available even though insoluble, while compounds which acidify the soil restore bivalent manganese permanently to the system and so cure the deficiency.

This report deals only with results obtained in plot and pot tests, with a review of the relative values of various methods of treating the soil in order to overcome the trouble. It is hoped that further chemical experiments concerning the forms and transformations of manganese in the soil may be published at a later date. The introductory account that has just been given is inadequate and some of the theory will probably have to be modified, but it will serve as a background for the experiments on plants that are recorded here.

The possible treatments of the disease are:—

(*a*) Thorough acidification of the soil with sulphur or otherwise.

(*b*) Addition of ammonium sulphate at or about the time of sowing. (This is equivalent to a minor and local acidification of the soil.)

(*c*) Addition of soluble or easily available compounds of manganese with the seed.

(*d*) Spraying the crop with dilute manganese sulphate as soon as symptoms of deficiency occur.

(*e*) Waterlogging for two or three weeks before sowing.

(*f*) Sterilizing the soil with formalin or some other suitable compound.

Of these methods, treatment with sulphur has already been shown to overcome the deficiency disease and to give better results with wheat than even large additions of manganese. In Europe and North America, however, where large areas of soil are deficient, little use has been made of sulphur, and the only acidic material used is ammonium sulphate, which would often be used in any case as a source of nitrogen. A comparison of sulphur and ammonium sulphate has therefore been made in plot experiments to be described. Method (*c*)—addition of soluble compounds of manganese with the seed—always increases the yield of both straw and grain, and is the only practicable method on highly calcareous soils, such as that of Corny Point, South Australia, where barley is sown (5) with a manganiferous superphosphate drilled in with the seed. Method (*d*)—the use of manganese sulphate as a spray—causes a

spectacular recovery of sick plants, though two or three sprayings may be needed. Methods (*e*) and (*f*) can be tried only in pot tests; the former (waterlogging) has been included in this work, but not the latter (sterilizing) which, however, has given spectacular results in the hands of Gerretsen (1).

Plot Experiments in 1934 to 1938.

Experiments were carried out in these years on the same plots as in 1932–3; the results of the earlier experiments have been reported (2). The soil is a grey sandy loam with 0.2 per cent. $CaCO_3$ and of surface pH about 7.5, uniform in texture to a depth of eighteen inches and overlying a yellow clay. The surface soil has not been developed in situ and probably consists of sweepings from the roads of crushed basalt which formerly served Melbourne. Twenty plots each of one square yard are available so that five treatments can be replicated four times. Experimental errors are inevitably large on such small plots, but differences between treatments are often highly significant in spite of this, and the same differences occur again in subsequent years, thus greatly increasing the significance of the results. In previous years, in which wheat had been grown continuously, the best yields were found on the four plots which had been brought by sulphur to a pH of 6.0 to 6.5. Twelve other plots had been left alkaline and had been given $MnSO_4$ in various ways. The addition of manganese always led to yields higher than the controls though residual effects one year after application were poor.

Plot Experiments in 1934.

Experiments in 1934 were designed partly to confirm previous results, partly to compare the effects of ammonium salts with nitrates as a source of nitrogen on this soil. The plots were treated as follows:—the control plots (A), the sulphured plots (B), and the plots (C) that had been most heavily treated with manganese in the two previous years (4 cwt. per acre $MnSO_4$ crystals), were sown with 2 cwt. superphosphate and 260 lb. $NaNO_3$; of the two other sets of plots, those given $MnSO_4$ with the seed in 1933 (D) were again given 1 cwt. per acre $MnSO_4$ crystals with the seed, as well as the same superphosphate and nitrate as the controls, while the plots tested for residual effect of manganese in 1933 (E) were given 2 cwt. superphosphate and 200 lb. ammonium sulphate. In this way all plots were given equal amounts of nitrogen.

Free Gallipoli wheat was sown on May 22nd, during a very dry spell which lasted for three weeks longer. Germination was slow and patchy on all the plots given $NaNO_3$, but was normal and uniform on the four plots given ammonium sulphate. These

plots (E) were outstanding throughout the winter, both in colour and in height. They had also produced the greatest number of tillers on October 3rd, when tillers on the other plots fell in the same order as in 1933, i.e., the $MnSO_4$ plots (D) were superior to the controls (though barely significantly) while the sulphured plots (B) again showed no increase over the controls; the tillers of (B) were, however, decidedly strong, and the total weight of the crop at this stage could not have been so much in favour of (E) compared with (B) as the tiller count indicates.

On October 10th there began a two-month spell of exceptionally wet weather, during which thirteen inches of rain fell, thus prolonging the growing season. However, the effects of sulphur and manganese were the same as in more normal years. The sulphured plots performed far better than any others during October and November, excelling in survival rate of tillers to ears, and especially in the weight of grain per ear. The $MnSO_4$ plots (D) also showed high figures for these values. The ammonium sulphate plots, however, fell right back and produced comparatively poor ears. There was a heavy incidence of foot-rot (*Ophiobolus graminis*) on all the alkaline plots, including a considerable amount even on the manganese-treated plots (D) where the plants were free from manganese deficiency disease and would have been expected to be more resistant. The acidic plots, however, were fairly free from disease.

The results of this year's work (Table I.) confirm those of former years. It is interesting to notice the all-round superiority of this year's manganese (D) over residual manganese (C); although in fact the soil of (C) contained 33 per cent. more added manganese than (D), this added manganese in plots (C) had evidently become much less available by the winter of 1934. The approximate equality of (B) and (D) is similar to what was found in 1932, but is in contrast to the marked superiority of sulphur over added manganese in 1933.

TABLE I.—FREE GALLIPOLI WHEAT, 1934.

—	Tillers.		Ears.			Grain.	
	Per Plant.	Per Sq. Yd.	Per Sq. Yd.	Percentage Surviving.	Gm. per Ear.	Bushel per Acre. Mean.	Bushel per Acre. Range.
A. Control	2·93	225	105	47	0·58	10·9	7·8–14·6
B. Sulphur	3·24	223	**158**	**71**	**1·16**	**32·6**	26·7–41·6
C. $MnSO_4$, Residual ..	3·00	233	127	55	0·75	**17·0**	16·2–18·1
D $MnSO_4$, with seed ..	3·13	264	**183**	**69**	**0·94**	**30·5**	29·5–32·0
E. Am_2SO_4	**3·46**	**300**	**174**	58	0·51	15·7	11·2–21·5

Standard error of mean of four plots, 1·88 bushels per acre.
Figures significantly different from control are in black.

The most interesting result, however, is the comparison of thorough acidification (B) with the use of ammonium sulphate (E). This comparison gives opposite results according as the crop is cut in the spring or grown for grain. It should be noted that the conditions are weighted in favour of (E), which had received a dressing of $MnSO_4$ two years before; this residual manganese should be made available by the ammonium sulphate more easily than the rest of the soil's manganese. In spite of this, the plants of (E) deteriorated during the last two months of growth.

Plot Experiments in 1935.

Since the wheat had suffered badly in 1934 from *Ophiobolus*, the experimental crop chosen in 1935 was Algerian oats. Experiments were designed to answer the following problems:—

1. Manganese deficiency has been dealt with either by keeping the soil alkaline and adding soluble manganese at sowing, or by acidifying the soil without adding any manganese. The latter method produces a healthier, and in some years a bigger crop of grain than does the former, but tillering on the acidified plots has shown no increase over the control plots and has been markedly below that of the alkaline plots to which $MnSO_4$ was added. This behaviour may be due to a difference in the forms in which manganese exists in the soil, or else to a general effect connected with pH and lime status. This could be tested by comparing the two treatments, (*a*) sulphur alone, and (*b*) sulphur with $MnSO_4$ at sowing.

2. The residual effect of a previous treatment with $MnSO_4$ has been shown (2) to be strikingly small. The author suggested that this was due to the completeness of precipitation of the added manganese in the surface inch or two of soil; and chemical analysis showed that this precipitation had in fact taken place. Information on the effect of thorough mixing of the surface ten inches of soil should settle this issue.

3. It would be useful to confirm the conclusions of 1934 regarding the inferiority of an ordinary dressing of ammonium sulphate to a heavy sulphuring.

The twenty plots were divided as before into five groups each of four replications, as follows:—

A. Control, no manganese added at any time.
B. Sulphured in 1932 and 1933, no manganese added at any time.
C. Alkaline, given 4 cwt. per acre $MnSO_4$ in 1932–1933. These were thoroughly mixed to a depth of ten inches just before sowing, but no more manganese was added.
D. Alkaline, given 1 cwt. per acre $MnSO_4$ in each year, 1932–3–4. Not dug at any time.

E. Given 1 cwt. $MnSO_4$ in 1932 and made acidic with excess sulphur in 1935. 56 lb. per acre $MnSO_4$ crystals added with seed in 1935.

Plots A, B, C, and E were sown with superphosphate and sodium nitrate; plots D were sown with superphosphate and ammonium sulphate. The total amount of nitrogen (48 lb. per acre) was the same for each plot. The first of the problems mentioned above should be solved by comparing B with E, the second by comparing C with A and D, the third by comparing D with B and E.

The seed was put in in the last week of May. Germination was uniformly good. As in 1934, the plants that had been given their nitrogen as ammonium sulphate showed a better colour and were taller during the early stages of growth. Some of the plants of group E, however (sulphur and $MnSO_4$), made poor growth at first, and many leaves showed a red colour at the tip. A few of the worst affected plants on these plots remained stunted to the end of the experiment, but the majority recovered, as described below. These toxic symptoms were evidently due to the unintentionally high acidity of the soil, which had a mean pH of 4.3 over the surface six inches; the added manganese probably made conditions worse.

The symptoms of grey-speck (manganese deficiency) became marked by 21st July—an earlier date than had been noticed for wheat, which is less sensitive than oats. The affected areas included all the alkaline plots (A, C, D) and patches on the previously sulphured plots (B). These bad patches had a mean pH value of 6.8, while healthy patches on the same plots had a mean pH of 5.7—a correlation with pH that has often been noticed elsewhere. By the end of August, the plants of treatment C (residual manganese, dug in) were somewhat healthier than those of treatment D (residual manganese, not dug in); these in turn were rather better than the controls (A). During September, however, all the plants on these twelve alkaline plots (A, C, D) died, and during October their place was taken by a vigorous growth of Wimmera rye-grass (*Lolium subulatum*) together with other plants, notably *Phalaris minor, Briza minor,* and *Vicia sativa.*

Grain-bearing heads were confined to the plants of treatment E (which recovered very well from their earlier poisoning), and to the more acidic patches of treatment B. The yield of the former plots was 60 per cent. above that of the latter. Since only five of the eight sulphured plots were uniformly free from grey-speck, the results do not provide a clear answer to the first of the three problems at the beginning of this section, concerning the reason for the low tillering of wheat on the sulphured plots, though it seems likely that pH is the main factor. The inferiority

of ammonium sulphate to sulphur is again strikingly confirmed, while the failure of the plots that had been thoroughly dug shows that the absence of a good residual effect of manganese sulphate cannot be due, as the author suggested, to a lack of mixing of the surface layers with the rest of the soil, but must be due to a change in the nature of the manganese compounds concerned.

PLOT EXPERIMENTS IN 1936.

The work of previous years has shown that the addition of large amounts of manganese to the soil here studied has only a slight residual effect in the years after the application, even if the soil is thoroughly mixed to a depth of eight inches or so. On the other hand, the addition of 80 parts per million of manganese in the form of "active" manganic oxide has made it possible for oats to grow healthily on the highly-deficient soil from Mount Gambier in the second year after application (see below). A waterlogging of two weeks also has kept a pot of Mount Gambier soil healthy for four years at least, after the waterlogging. It is of interest therefore, to try to find out whether extremely heavy applications of manganese compounds will restore the University soil permanently to a state in which it will grow healthy oats or wheat. In 1936, besides confirmatory tests with sulphur and ammonium sulphate, the further treatments were tried of 12 grams per square yard of manganese as freshly precipitated MnO_2 (or about 60 p.p.m. Mn) well mixed with the surface six inches of soil, and the incorporation into a plot of about 50 Kg. of the soil of the same plot which had had three weeks' waterlogging in a pot. Neither of these treatments succeeded in overcoming the disease of the oats.

The plants on the strongly acidic soil looked poor during June and July, but later made excellent growth. The plants given ammonium sulphate developed "grey speck" during the first warm days of August, and steadily deteriorated thereafter. The only plants which yielded well were those on the acidic soil and those given $MnSO_4$ with the seed, the former being significantly better. The effect of manganese deficiency is so much more acute on oats than on wheat that the sulphured plots are already far superior to controls when tillers are counted, though the manganese-treated, alkaline plots produce rather more tillers than the sulphured plots.

Another treatment which was tried on other plots and which proved futile was a heavy dressing of blood manure (which contains very little manganese and differs in this respect from farmyard manure). In another experiment four plots were sown with seed which had been soaked for two days in 0.1 per cent. $KMnO_4$ and was deeply stained with MnO_2. The plants

on these plots were decidedly healthier than controls or manured plots during the winter and until the end of August, but collapsed with the first warm days of spring and finally produced only insignificant amounts of grain.

Plot Experiments in 1937.

While it appears that oats do not benefit from any residual effect of added manganese compounds on this soil, it is possible that the less sensitive wheat plant may do so. Wheat was therefore tried this year, and the plots that had been heavily treated with manganese dioxide or mixed with previously waterlogged soil were compared with those on which $MnSO_4$ was applied with the seed. At the same time a new line of inquiry was made. A few European workers have claimed that a heavy dressing of quicklime improves the growth of oats on deficient soils. Since this suggests that there is an upper limit of pH, as well as a lower limit, to the incidence of "grey speck" disease, the problem may best be approached by adding alkaline material to bring the pH well above 8, preferably to about 9. Four plots which had never received additional manganese but had been sulphured some years before (Plots B of 1934) were treated with caustic soda at the rate of about 2 tons per acre.

The growth on the acid plots (pH 4.5–5.0) was the same as usual; there were fewer tillers in September than on the control plots, but the survival rate was very high (87 per cent.) and the average weight of the ears was much higher than on any other plots, so that the final yield was the best, though the difference between the acidic plots and the manganese-treated plots is not significant. (The figures here tabulated refer to the weight of the whole ear and not of the separated grain.) The residual effect of a heavy application of manganese compounds two years previously appears to come close to that of an application of $MnSO_4$ with the seed—a result in marked contrast to that obtained with oats. Finally the caustic soda had such a bad effect on the soil that both germination and subsequent growth were very poor. Results are collected in Table II.

Table II.—Ghurka Wheat, 1937.

Treatment.	Tillers.		Ears.			Total Yield Gm. per Sq. Yd.
	Per Plant.	Per Sq. Yd.	Per Sq. Yd.	Percentage Surviving.	Gm. per Ear.	
A. Control	2·06	167	125	75	0·82	103
B. Caustic soda	1·93	44	28	64	0·86	24
C. $MnSO_4$, Residual	2·27	179	132	74	1·19	**157**
D. $MnSO_4$, with seed	2·16	180	148	82	1·26	**186**
E. Acidic	2·00	142	123	87	1·64	**202**

Standard error of mean of total yield, 15·5 gm.
Yields significantly greater than control are in black.

Plot Experiments in 1938.

These experiments were designed with two main ends in view. Firstly, it was desirable to repeat the previous year's experiment with caustic soda under more favourable conditions for germination, and this was achieved by digging gypsum into the surface layers shortly before seeding. Secondly, it would be interesting to compare the growth of plants on soil that has been acidified or given some other improving treatment, with the growth of plants which are sprayed with a soluble manganese salt as soon as the symptoms of deficiency occur, but which otherwise grow on " deficient " soil.

The plots this year comprised:—(A). Soil untreated but plants sprayed with 1 per cent. $MnSO_4$ as soon as deficiency shows; (B). Highly alkaline, treated with gypsum; (C). and (D). Slightly alkaline, residual manganese only; (E). Highly acidic. This arrangement left the plots without the conventional " controls." However, the " residual manganese " plots could be relied on to give very low yields with which the others could profitably be compared. The oat variety Dawn was sown, and calcium nitrate was added to all plots at the rate of 1 cwt. per acre. The symptoms of grey speck appeared about the middle of August. The plants of group (A) were sprayed with a fine spray of 1 per cent. $MnSO_4$ (so as to ensure that every leaf was wetted) on 16th and again on 26th August. The plants immediately recovered, and the symptoms did not reappear. The highly alkaline plots at this time showed surprisingly good growth, with as healthy a colour as those on the acid soil.

When the tillers were counted early in October the acidic and highly alkaline plots were outstanding (see Table III.). However, the latter plots were very patchy, with some healthy plants and some sick. Samples of surface soil taken under healthy plants had a pH of 8.5 to 8.7, while samples around the sick plants had a pH of about 7.5.

Table III.—Dawn Oats, 1938.

Treatment.	Tillers.	Ears.		Grain.		Total Yield Gm. per Sq. Yd.
	Per Sq. Yd.	Per Sq. Yd.	Percentage Surviving.	Gm. per Ear.	Gm. per Sq. Yd.	
A. Sprayed	**151**	**114**	**76**	0·61	**70**	**312**
B. Caustic soda	**213**	**99**	46	0·56	**54**	**294**
C. Residual Mn	132	51	38	0·33	17	105
D. Residual Mn	139	70	50	0·47	33	152
E. Acidic	**196**	**147***	**75**	0·82	**120***	**463***

Figures significantly greater than " controls " (C) are in black.
Those significantly the greatest in the column are also asterisked.

The spring was very dry and warm, no rain of importance falling after early August, and the grain ripened in late November. As the figures show, the acidic plots gave the usual high survival of tillers to grain-bearing heads and a high yield of grain per head. The sprayed plants also showed a good survival of tillers but a relatively poor yield of grain. This no doubt was due to the fact that the primordia had already suffered from manganese deficiency before the symptoms of "grey speck" appeared. The soda-treated plots did not fulfil their earlier promise; but the final yield included a number of large plants bearing much grain (from the most alkaline patches) besides a greater number of typically "deficient" plants.

Summary and Discussion of Plot Experiments.

The results up to date may be summed up as follows:—

Oats.

1. *Acidification of the soil with sulphur* to below pH 6.5 gives the highest yields both of straw and of grain, and its superiority over the controls appears in the middle of August.

2. *Application of ammonium sulphate* with the seed causes somewhat increased vegetative growth during June and July only, and thereafter has no advantage over controls which have been given nitrogen as nitrate.

3. *Alkalinization of the soil with caustic soda* causes a marked improvement, especially in vegetative growth up to the end of September. This improvement appears to depend on raising the pH of the soil over 8.5.

4. *Application of manganese sulphate* with the seed causes an increase in tillering (24 per cent. in one case) but the survival of tillers to heads and the final yield are less than on acidic plots. The optimum application of manganese sulphate has not been tested, but the routine rate in these experiments was 1 cwt. of the crystalline salt per acre.

5. *The residual effect* of manganese compounds applied to this soil in the preceding year is slight.

6. *Spraying plants with $MnSO_4$* as soon as they develop symptoms of "grey speck" causes immediate improvement, but both the tillering and the yield of grain are low in consequence of the deficiency during the first two months of growth.

7. *The incorporation of blood manure* into the soil is useless.

Wheat.

1. *Acidification of the soil with sulphur* to below pH 6.5 causes rather poorer growth than on the control plots during the winter months, and a slight depression in tillering. In late September, however, the tillers are strong, and the plants on acid soil have

a better colour from that time on. Survival of tillers to ears and weight of grain per ear are high, and the final yield is better than is obtained with any other treatment.

2. *Application of ammonium sulphate* with the seed causes much better winter growth and a greater production of tillers in late September, than any other treatment; the total weight at this time, however, may not be greater than with other successful treatments. The survival of the tillers to ears and the production of grain per ear are poor, and the final yield is little better than on the controls.

3. *Application of manganese sulphate* with the seed causes an increase in tillering, up to 30 per cent. compared with controls, but the survival of tillers to ears and the weight of grain per head, though superior to controls, are less good than on acidic plots, and the final yield of grain is never greater and is sometimes less than on the acidic plots.

4. *The residual effect* of manganese compounds applied in moderate amounts to this soil in the preceding year is marked, though it is less than that of a fresh application. However, a heavy application of freshly precipitated manganese oxide, well mixed with the top eight inches of soil, appears to exert a residual effect as good as that of a fresh application.

These results may be compared with those of Townsend and Wedgworth (6) who grew French beans (*Phaseolus vulgaris*) on a highly-deficient soil consisting of burned peat, and studied both the immediate and the residual effect of adding sulphur or manganese sulphate to the soil. They found that heavy applications of manganese sulphate (100 lb. per acre) did immediate good, but this good effect could hardly be seen in the succeeding crop. Light applications of sulphur (5 cwt. per acre), which were insufficient to bring the pH into the acid region, had a good effect which was only temporary. A heavy application of sulphur which brought the pH down to 6.0 appeared to do lasting good, although its immediate effect was to depress the yield. It appears that some intermediate product of oxidation such as thiosulphate, may be responsible both for the temporary good effect of small amounts of sulphur (due to its reducing action) and for the temporary bad effect of larger amounts (due to direct toxicity). A spray of dilute manganous sulphate led to excellent vegetative growth; but these workers did not compare the various treatments with regard to reproductive growth.

Pot Tests.

Pot tests carried on during the last five years have been directed to two ends, namely, attempting to cure deficient soils, and attempting to make healthy soils deficient by heavy liming.

EXPERIMENTS WITH DEFICIENT SOILS.

The former work has been especially concerned with the soil from Mount Gambier (South Australia), where Samuel and Piper (4) made the first Australian studies of manganese deficiency in the field. This soil is a deep, permeable sandy loam, derived from basaltic ash, and highly immature. Manganese deficiency of cereals occurs on this soil type in places where the reaction is neutral or alkaline; the free calcium carbonate which is responsible for the alkalinity may be derived from the layers of Tertiary limestone through which the volcanic ash burst its way. The various treatments that have been attempted on a calcareous sample of this soil are described below. In every experiment a sensitive variety of oats was the test plant, viz., Algerian or Dawn for winter and spring, and Tasmanian White Oats for early summer. The pots are 3 feet high and hold 25 Kg. of soil.

(1) Acidification to a pH value of 6.5 or less. This brings about a complete cure, as was reported by Samuel and Piper (4). Such treatment is of little practical value, since huge amounts of acid are needed to destroy the free calcium carbonate.

(2) Addition of a manganese compound, uniformly mixed with the whole of the soil in the pot so far as to ensure that the roots reach the manganese. Two pots were used here, one of which was given crystalline manganese sulphate and the other freshly prepared "active" manganese dioxide, completely free of water-soluble manganese. The $MnSO_4$ was added at the rate of twenty parts of manganese per million of soil, and the MnO_2 at the rate of 80 parts. This was done in October, 1934. The plants on the treated pots made excellent growth during the next two months, while the two controls suffered severely from grey speck (part of this experiment was reported in a previous paper). At least one crop of oats has been grown on these pots in each year since then, and the plants have always done much better than the controls, which regularly succumb to grey speck. Slight symptons of manganese deficiency have occasionally been noted on the leaves of the pot that was given manganese dioxide, but the plants have always recovered later. Evidently the long-term residual effect of added manganese on this soil is far more marked than on the University soil. No reason for such a difference can be suggested, but the relative importance of various stages in the cycle of biological and non-biological changes through which manganese moves must differ from one soil to another. There remains, of course, the possibility that interactions with other elements may be involved.

(3) Prolonged waterlogging. When the pots were prepared in October, 1934, the outlet from one pot was closed and water was added so as to stand about an inch above the level of the soil. After four weeks of waterlogging, drainage was restored. Very sick oat plants were immediately transplanted into this

pot, and they proceeded to make excellent growth. The subsequent history of this pot has been remarkable; with no addition of manganese at any time and with normal drainage (which is naturally very free on this soil) six healthy crops of oats have been grown. On one occasion only, during a hot spell in December, 1937, a few leaves showed slight symptoms of grey speck; but there were no symptoms in 1938.

It appears therefore that a single waterlogging has brought about a lasting cure. This soil normally contains a large reserve of manganic oxide just below the level of availability to plants (2, p. 250), and the waterlogging has apparently promoted some of this reserve to a more available state. Oat plants growing on this pot contained the high figure of 54 parts of manganese per million in 1935. Unfortunately, this cure does not seem to be a practicable one in the field. The winter rainfall at Mount Gambier is heavy, averaging 12 inches from June to August inclusive, but this water soaks quickly through the soil. One plausible method of inducing waterlogging in the field would be to make the soil highly alkaline with sodium carbonate or hydroxide and to rely on the hydrophilic properties of the resultant sodium clay to cause waterlogging during the winter. The soil would naturally have to be reclaimed later with gypsum. A preliminary experiment was done in 1938 to test this idea; 56 gm. of crystals of sodium carbonate was added to a pot of Mount Gambier soil, and water equivalent to about an inch of rain added every four days during August and September. The oats which were sown in the next month succumbed very quickly to manganese deficiency; this was not surprising, since the soil did not approach to a waterlogged condition during the period of treatment.

Pot tests were also carried on with a gravelly soil from the southern wheatbelt of Western Australia. This soil contains about 50 per cent. of ironstone pebbles about half an inch to an inch in diameter, and is of low fertility, apart from its manganese deficiency. The incorporation of freshly precipitated manganese dioxide into the pot of this soil greatly improved the growth of oats as compared with the control; a still better result was obtained by a fortnight's waterlogging, the results of which have persisted for two years.

The University soil was also waterlogged in a pot for three weeks, but the plants which subsequently grew on this soil suffered from manganese deficiency. It is surprising that the treatment which was so successful with two deficient sandy soils should fail with a third.

Attempts to Make Healthy Soils Deficient.

The author suggested previously that an extraction with a solution of quinol in normal ammonium acetate at pH 7 might serve to determine the amount of available manganese in a soil,

and that podzolic soils containing not more than 25 parts of such manganese per million might become "deficient" on liming to pH 7 or beyond. Tests in small pots have since been carried out, and they tend to confirm the above suggestion. The following figures (Table IV.) relate to the properties of certain soils from Southern Victoria; the "available" manganese is that which is extracted in the cold by normal ammonium acetate together with that which is extracted by a 0.2 per cent. solution of quinol in normal ammonium acetate. All the soils are podzolic and derived from sedimentary material, except the University soil. The Bellarine soil has been included for comparison, though it was not used for pot tests; this sample was taken from land adjoining an area on which oats had suffered from manganese deficiency following heavy liming several years earlier.

TABLE IV.—SOILS TESTED FOR EFFECT OF HEAVY LIMING.

—	Description and Location of Soil.					
	Light Grey Sandy Loam, Timboon.	Grey Fine Sandy Loam, Coleraine.	Grey Sandy Loam, University.	Grey Sandy Loam, Bellarine.	Grey Sand, Cranbourne.	Grey Sandy Loam, Narre Warren.
pH	5·3	5·8	5·0	5·4	3·4	5·6
Available Manganese p.p.m.	1	17	15	8	2	7

The treatments consisted of varying applications of calcium carbonate, the heaviest of which brought the pH of the soil above seven in each case. The experimental plant was oats, either Dawn or Algerian, and all pots were given an adequate supply of calcium nitrate and potassium phosphate.

1. *Timboon Soil.*—The plants on the alkaline pots suffered severely from manganese deficiency; this occurred as soon as the soil had been made alkaline.

2. *Coleraine.*—The first result of heavy liming was to cause greater growth on this soil, though symptoms of manganese deficiency also appeared. Three years after liming, the plants suffered severely from deficiency.

3. *University.*—The soil from some garden beds, which have never been limed, is the same in origin as that on which the experimental plots are now located. The first year after heavy liming, the oats made better growth than on the acid soil, but in the second year they succumbed to manganese deficiency.

4. *Cranbourne.*—This is an extremely poor soil which must be limed before ordinary crops will grow well on it. Overliming, however, immediately brings about symptoms of deficiency.

5. *Narre Warren*.—During the twelve months which have passed since samples of this soil were brought to pH 7.3 in pots, improved growth has been the only result of liming.

From these experiments it appears that a considerable time must elapse before certain soils with a fair original reserve of available manganese are adversely affected by liming to above pH 7, but where the reserve is low, deficiency appears soon after the lime is applied.

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[PROC. ROY. SOC. VICTORIA, 52 (N.S.), PT. I., 1939.]

ART VIII.—*Studies on the Australian Clavariacea, Part* III.

By STELLA G. M. FAWCETT.

[Read 13th July, 1939; issued separately, 1st March, 1940.]

Genus **Clavaria** (*continued*).

In two previous papers (1 and 2) Groups 1, 2, 3, 4, 7, 8, 9 and 10 of the genus *Clavaria* were dealt with. In this part additions are made to Groups 9 and 10 of the genus and in addition one species of *Physalacria* is described.

GROUP 10 (continued).

CLAVARIA FLAVA Fr. ex Schaeff. Fung. Bavar. pl. 175, 1763.

? *C. lutea* Venturi. 1 miceti del agro Bresciano, p. 36, pl. 41, fig. 4, 1845-1860.

C. flavo-Brunescens Atk. Ann. Myc. 7, 367, 1909.

Plate VI, figs. 1 and 2, text. fig. 1*d*.

Plate VII, fig. 5.

Plants very variable in size, ranging from 4-18 cm. diameter and 5-16 cm. height. Base comparatively stout and obtuse, occasionally tapering, not deeply rooting, smooth, or with a few broad, shallow furrows. Arrangement of the branches variable: a large number of small branches, which soon divide to form the ultimate tips, may arise from the top of the trunk, or there may be a few large primary divisions which branch once or twice to form the ultimate tips. The latter are usually rather delicate and bluntly cusped, forming a close mass, sometimes they are obtuse, few in number and thick.

Axils for the most part rounded, branches spreading, lacking a strongly upright tendency. Surface of branches usually smooth but occasionally finely and evenly rugose. Colour, Maize Yellow, Chrome Yellow, Antimony Yellow, base whitish, not staining when bruised. Flesh creamy or white, paler than the surface, crisp and brittle in youth, becoming softer and more translucent with age. Taste and odour, mild, slightly fungal.

Spores about Maize Yellow in colour, elliptical, with an obliquely terminal mucro, distinctly and evenly roughened, $3.2–4.3 \times 7–11\ \mu$. Habitat—on the ground in forests.

This species is very variable in form but its colour is distinct and is generally described as a clear pale yellow without a tint of orange. It approaches *C. ochraceo-salmonicolor* in form and

colour but may be distinguished from it by its fine, unexpanded tips. Although, in colour, it resembles *C. sinapicolor,* it may be distinguished from this species by its solid, compact, relatively smooth base, by its spreading habit and short branches and mild indistinct odour.

CLAVARIA FLAVA var. AUREA Coker. Clavarias of the U.S. and Canada, p. 124, pl. 38 and 85. Chapel Hill, 1923.

(Plate VII, fig. 1, text fig. 1. (E).)

Plants branched and bulky, often very large (25 cm. broad), usually about 10 cm. high and 8 cm. broad. Branching irregularly and sub-dichotomously from a short, stout base into very many branches which divide three, four or five times before the ultimate tips are formed. These are bluntly rounded, and short. The whole forms a close mass. Branches cylindrical, generally smooth, but tending to be rugose in age; axils acute. Flesh crisp and brittle in youth, becoming much softer and rather lax at maturity, somewhat translucent. Colour, base whitish for a variable distance, body of plant Apricot Buff to Orange Buff or Ochraceous Buff. Tips, Capucine Yellow or paler, becoming concolorous in age. Flesh coloured like the surface but with a distinctly pinkish tinge which it retains throughout the life of the plant. In age, under moist conditions, the colour of the body of the plant does not change appreciably but in a dry atmosphere the entire plant tends to become Pinkish Cinnamon or Cinnamon Buff. Taste and odour indistinct, mild.

Spores faintly, but evenly roughened, elliptical with a broad, obliquely terminal mucro, 3.5–4.5 (occasionally 4.8) $\times$ 7–9.5 μ. Habitat—on ground in forests and heathlands, very abundant on burnt soil.

This plant may be distinguished from the typical *C. flava* by its richer colour and pinkish, rather translucent flesh and from the deeper coloured form of *C. ochraceo-salmonicolor* by its unexpanded, paler tips and by the colour of the flesh. Intermediate forms are very difficult of identification.

CLAVARIA OCHRACEO-SALMONICOLOR Clel. Trans. Roy. Soc. S.A., lv, 1931, pp. 152-160.

(Plate VI, fig. 3, fig. 4, text fig. 1.(F.))

Plants branched, large or medium-sized, 5-15 cm. high and 5-14 cm. broad. Trunk distinct, stout, solid, 2-4 cm. broad; giving rise to numerous primary branches which divide three to five times before the ultimate tips are formed. Axils acute, branches with strongly developed, broad longitudinal furrows which originate in the axils. Ultimate tips rather broadly expanded, consisting of two to five more or less hemispherical

knobs. The tips and upper branches form a very close cauliflower-like mass but with the tips distinct and not fused. In fresh specimens the tips do not differ in colour and texture from the body of the plant but in the dried state they show a difference in colour, being near Honey Yellow, while the body of the plant is about Cinnamon Buff or Pinkish Buff. Flesh white or pale, solid, brittle. Taste and odour indistinct. Colour (of living plants) very variable, Naples Yellow, Antimony Yellow, pale Orange Yellow, Capucene Buff, Capucine Orange. Tips generally slightly darker in colour than the rest of the plant.

Spores ochraceous, evenly and finely roughened, oblong elliptical, with an obliquely terminal mucro, 8.1–10.5 × 3.9–5.2 μ. Habitat—on the ground in forested or heathy areas.

The above description is considerably more restricted than that given by Cleland. Although the species has a wide colour range, its form is fairly constant and the spores do not vary a great deal in length. From the range of spore size given by Cleland (7.5–13 × 3.7–5.5 μ) it would appear that he had included *C. flava* and its variety *aurea* and possibly *C. capitata*, all of which show colours similar to those of *C. ochraceo-salmonicolor*.

The species may be distinguished from *C. flava* and *C. flava* var. *aurea* by its expanded tips, and narrow axils. It may be separated from *C. capitata* by its non-viscid and separate tips and shorter spores.

Clavaria filicicola n. sp.

(Plate VI, figs. 4 and 5, text fig. 1. (H).)

Plantae ramosae, parvae, plerumque 2-4 cm. altae, in forma variae, surgentes e mycelio denso et albo quod se cum fibris truncae Dicksoniae conjungit. Basis plantae aliquantum crassa, abrupte e mycelio surgens, sine radicibus perspicuis, saepe tomentosa a mycelio. Rami, qui duo et magni aut plures et minores esse possunt, sine discrimine oriuntur. Hi in vicem raro se dividunt et plerumque apices ultimos portant. Apices acutissimi sunt parvi et nonnumquam divaricantes sunt. Caro plantae est solida et ubi novella est facile frangi potest sed cum aetate mollior et flexibilior fit. Sapor et odor nullus. Color plantae juvenilis alba, grandioris "Maize Yellow" ad "Ochraceous Buff." Hymenium levis, in similitudenem pulveris aetate mutatem est. Basidia quattuor sterigmata habent. Sporae "Maize Yellow" in massa, perspicue asperae, quae saepe collabuntur, oblongo-ellipsoidae cum mucrone obtuso et obliquo, 5.6–7 × 3.6–3.9 μ. *Hab. in trunca Dicksoniae antarcticae plerumque aut inter bases frondium viventium aut infra eas. Loc. Turton's Pass, Apollo Bay. Mai.*

Plants branched, small, usually 2–4 cm. high, rather variable in form, arising from a dense white mycelium which binds together the fibres of the Dicksonia trunk. Base of plant stout, in relation to size of plant, often woolly from the mycelium, branching very irregularly into two large branches or into many crowded smaller ones which in turn may be very sparingly branched, but generally give rise to the ultimate tips which are very sharply pointed, small, and sometimes divaricating. Flesh solid, brittle in youth, becoming softer and more pliable in age. Taste and odour none. Colour, pure white when young, Maize Yellow to Ochraceous Buff when old.

Hymenium smooth, apparently powdery when old. Basidia with four sterigmata. Spores Maize Yellow in bulk, distinctly rough, often irregular by collapsing, when fresh, oblong elliptic with broad obliquely terminal mucro, 5.6–7 × 3.6–3.9 μ. Habitat—on trunks of *Dicksonia antarctica,* usually immediately below the crown of leaves. Locality—Turton's Pass, Apollo Bay. May.

This species most closely resembles *C. gracilis,* but may be distinguished from it by its stouter and more solitary habit, rough spores, lack of distinct odour, and chiefly by its very characteristic place of growth. *C. gracilis* is found only under pine trees.

CLAVARIA ABIETINA. *Non-Virescent Form.* Coker. Clav. U. S. and Canada, p. 182. Chapel Hill. 1923.

? *C. corrugata* Karst. Nat. Faun. et Flora Fenn., p. 371, 1868. (Text fig. 1. (G).)

Plants branched 3.7 cm. high and 2–5 cm. broad, growing in large colonies under *Pinus radiata,* arising from a dense white subiculum which mats the fallen needles together. Trunks stout, equal to about one-fifth of the plant in height, irregular and incrassated, deeply channelled in age, branching very irregularly, often palmately three or four times. The ultimate branches generally erect, but may be spreading, tips short, acute, spreading, usually produced in a palmate or cristate fashion, axils acute. Surface of young plants smooth, in older specimens much incrassated. Branches often fusing with one another, sometimes uniting the upper parts of separate plants by this process.

Flesh of densely interwoven hyphae, tough, opaque, often hollow or loosely stuffed in the centres of older branches, soft and rather flexible. Colour—Cream Buff, Chamois, Pinkish Buff. Tips whitish. Not staining when bruised. Smell slight, like radish, taste mild, indistinct.

Hymenium smooth in younger parts of plant, often double in older parts. Basidia with four sterigmata. Spores yellowish, oblong elliptical, often broader at the distal end, finely and evenly roughened, 6.2–8.1 × 3.1–4.3 μ. Locality—Sherbrooke, under *Pinus radiata.* May.

This plant may be distinguished from *C. gracilis,* which favours the same habitat, by its stouter habit and deeper colour. Cooke records *C. abietina* for Victoria giving the spore measurements as 7–10 × 4–6 μ and the habitat as "Fir woods." If the spore measurement is correct it is most likely that Cooke had *C. apiculata* (spores 3.7–4.6 × 7.4–9.2 μ) as the spores of the various forms of *C. abietina* are much smaller than this. If, however, the spore measurement is incorrect and Cooke really had a form of *C. abietina* it is possible that he had the *flaccida* form which Cleland has recorded (as *C. flaccida*) from Callitris woods in South Australia. It is most likely that Cooke's specimen was also collected in *Callitris* woods, as it must necessarily have been collected prior to 1892 when there were no extensive plantations of introduced Conifers in the State. There is also some evidence to show that in the past the various species of *Callitris* were known as "Firs."

In view of the constant association of *C. gracilis* and *C. abietina* (non-virescent form) with species of *Pinus,* it is most probable that they are not native and have been introduced with these trees; as, although many of the Victorian pine plantations abut on native forest and are growing under apparently similar conditions, neither *C. gracilis* nor *C. abietina* (non-virescent form) are found growing away from the pines in the native forest.

GENUS **Physalacria.** (Fr. ex. Schw.) Pk.

PHYSALACRIA INFLATA (Fr. ex. Schw.) Pk. Bull. Torrey Bot. Club, 9: 2: 1882.

(Plate VII, figs. 2 and 3, text fig. 1 (A), (B), (C).)

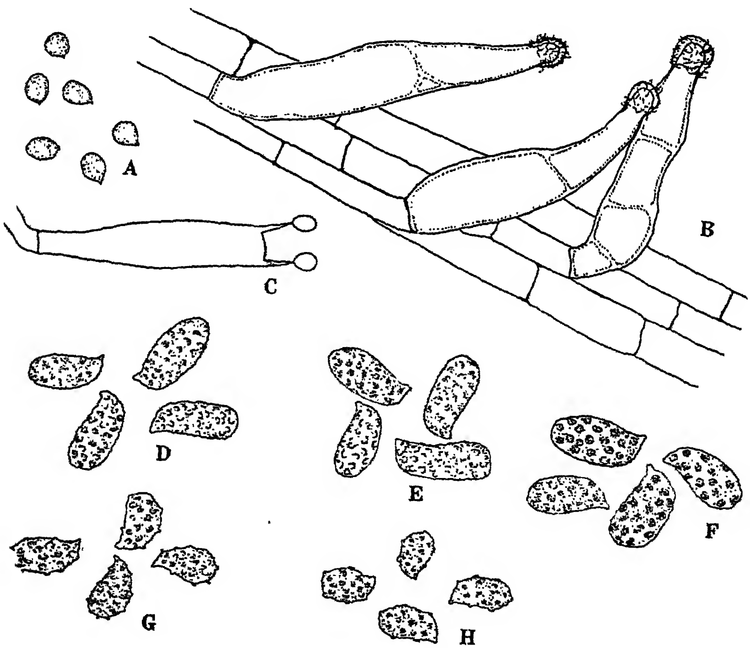
Plants small, usually 0.4–1 cm. high, occasionally 1.3 cm., at maturity, consisting of an irregularly-globose, swollen, thin-walled bladder, 0.3–0.5 cm. diameter, supported on a firm slender stalk 0.1–0.15 cm. diameter, and 0.3–0.6 cm. long. In some cases the irregularities of the head are confined to the undersurface and resemble gills as they radiate from the stalk. Frequently, the likeness to a small, white-spored Agaric is increased by the collapse of the upper part of the bladder over the lower. When young, the heads are almost uniformly globose. The plants most often occur in extensive colonies in groups of two or three, occasionally singly, or in dense clusters with the heads closely appressed and obscuring the stalks. Colour, when young, pure white; in age, yellowish, or brownish-white. Texture, rather membranous, resisting tearing.

Under the lens, the head and stalk appear to be covered in short, glistening bristles, owing to the presence of strongly projecting cystidia. These are irregularly cylindrical structures

bearing a knob-like process at the apex. This process is relatively thick-walled and on the outside is covered by a mucilaginous substance. The hymenium is sharply delimited, occurring only on the head, covering it entirely. Basidia inconspicuous among the cystidia, two-spored.

Spores smooth, white, sub-globose or elliptical, 2–3 × 3–4 μ. Mucro very inconspicuous. Habitat—on dead wood in very wet gullies. Localities: Sherbrooke, November, February, March; Ferny Glen, Apollo Bay, May. Not previously recorded for Australia.

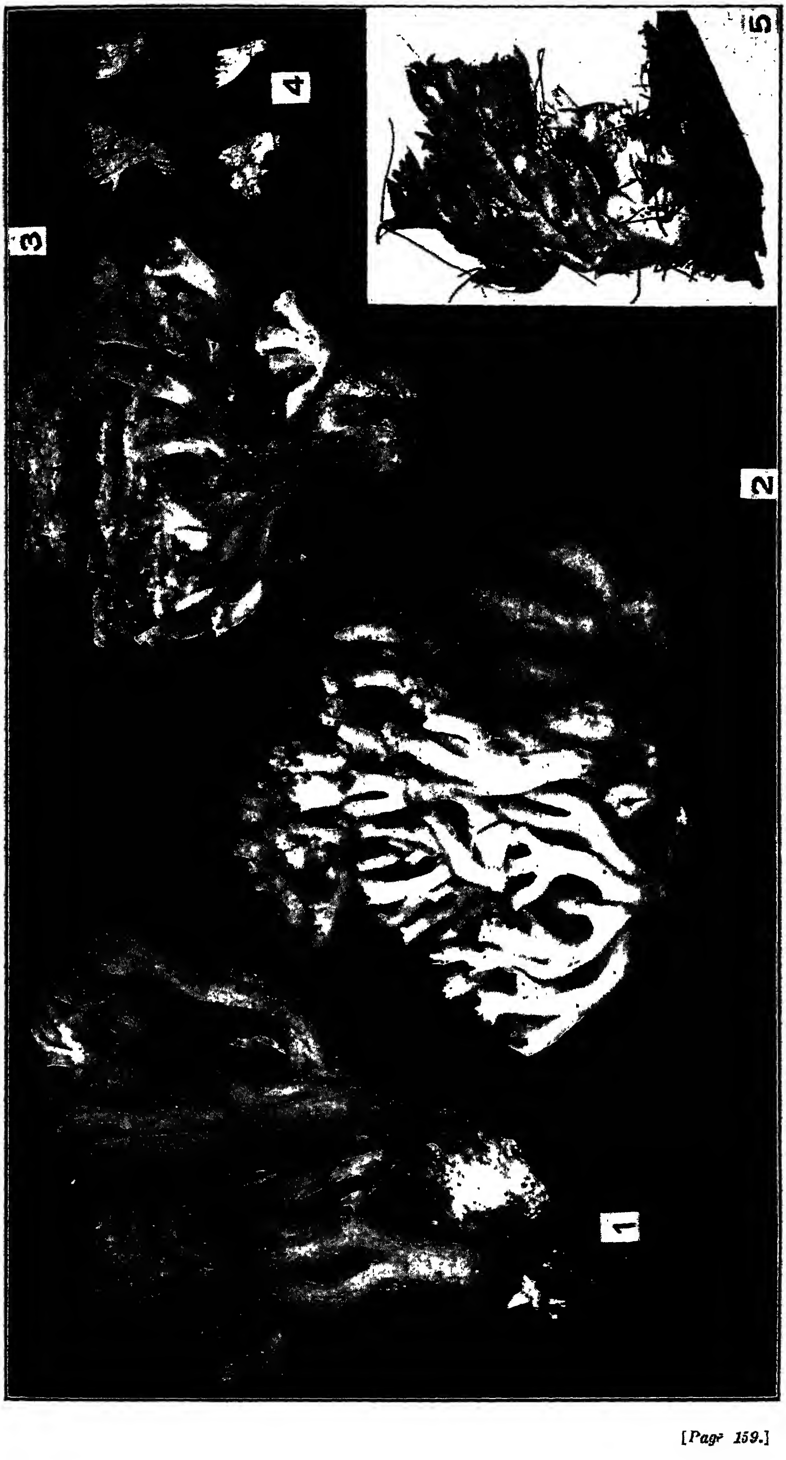
This plant has a very complicated history. De Schweinitz collected it and, giving it the manuscript name *Leotia inflata*, sent it to Fries, who, however, published it as *Mitrula inflata* (Elenchus Fungorum, Vol. 1, pp. 234 and 235), referring to de Schweinitz's name. Later, in Epicrisis (p. 584), he repeated the description with the name *Mitrula inflata albida*. In 1878, Cooke (Mycographica, p. 204) for no apparent reason, changed the name to *Spathularia inflata*. In 1882, Peck proved that the



TEXT FIGURE I.

A. Spores of *Physalacria inflata;* B. Cystidia from stem of *P. inflata;* C. Basidium of *P. inflata.*

Spores:—D. *C. flava.* E. *C. flava var. aurea.* F. *C. ochracco-salmonicolor.* G. *C. abietina, Non-virescent form of pines.* H. *C. filicicola.*
Magnification:—A, D, E, F, G, H, 1,125. B, C, 500.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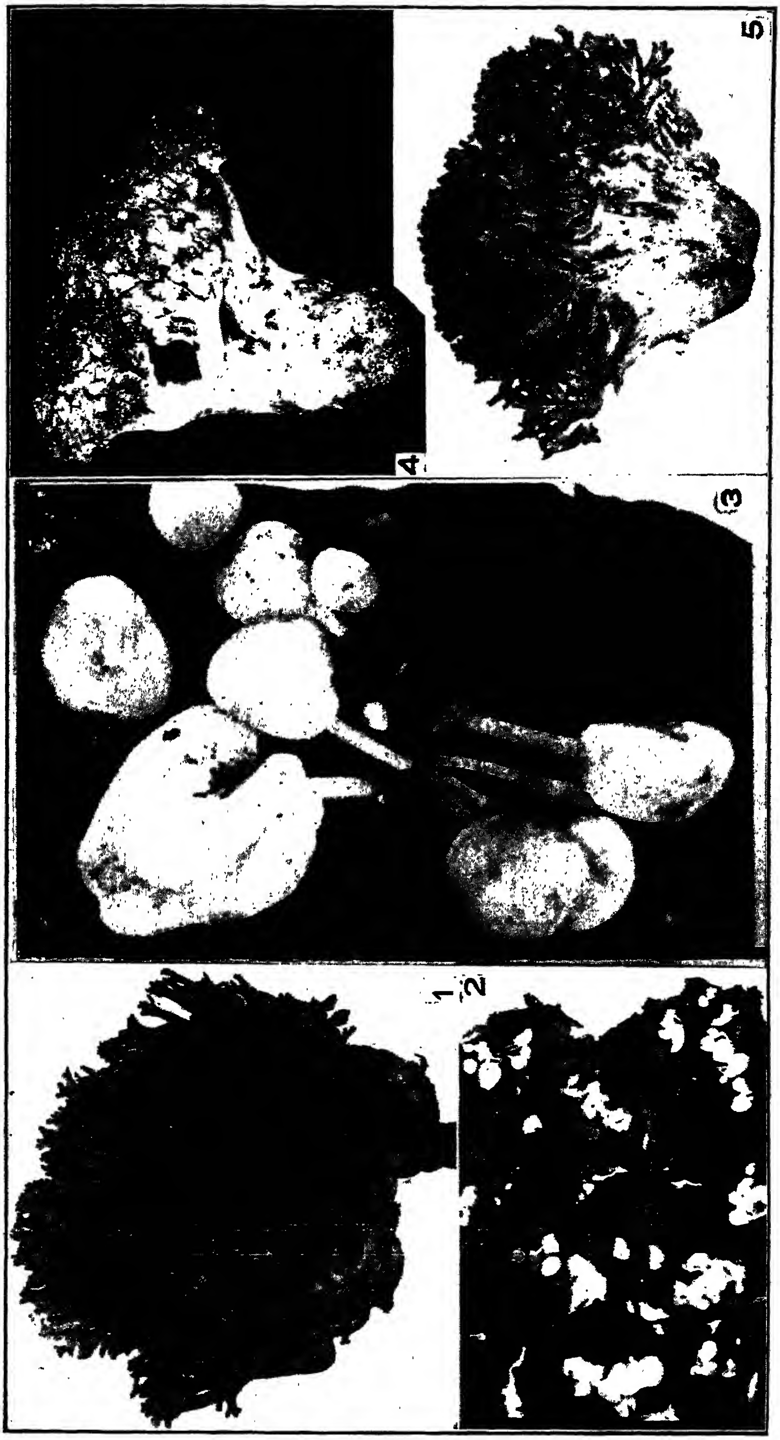
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plant was, in reality, a Basidiomycete, and suggested that the previous authors had mistaken the large cystidia for empty asci. As he found that the hymenium completely covered the head he placed the plant in the Clavariaceae, establishing the name *Physalacria.*

In 1923, Krieger (3) removed the genus to a primitive position in the Agaricaceae, renaming it *Eoagaricus.* This name, however, is not valid, as the Rules of Botanical Nomenclature do not permit such a change. He stated that the hymenium was confined to the under surface of the head and that the upper and under surfaces showed differences in texture and colour. He interpreted the irregularities which are frequently seen on the under surface of the older plants as primitive gills. In the Victorian plants the hymenium covers the entire head and there are no apparent differences in texture or colour between the upper and lower surfaces. There can be no doubt that our plants are correctly identified as they agree exactly with Peck's description. Thus there is no evidence in support of Krieger's statements. It is possible that the plants on which he based his work were abnormal. Therefore it seems that *Physalacria* should be retained in the Clavariaceae.

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Explanation of Plates.

Unless otherwise stated, all photographs are natural size.

PLATE VI.

1. *Clavaria flava.* Rugose plant.
2. *C. flava.* Smooth plant.
3. *C. ochraceo-salmonicolor.*
4. *C. filicicola.*
5. *C. filicicola.* (× 3).

PLATE VII.

1. *C. flava* var *aurea.*
2. *Physalacria inflata.*
3. *Physalacria inflata.* (× 9). Note cystidia on the stalks and heads.
4. *C. ochraceo-salmonicolor.*
5. *C. flava.*

[PROC. ROY. SOC. VICTORIA, 52 (N.S.), PT. I., 1940.]

ART. IX.—*The Shore Platforms of Mt. Martha, Port Phillip Bay, Victoria, Australia.*

By J. T. JUTSON, B.Sc., LL.B.

[Read 13th July, 1939; issued separately, 1st March, 1940.]

Contents.

Introduction.

The writer has previously considered (1) in a general way some of the wave-cut rock platforms of Port Phillip Bay and its immediate vicinity. The present paper is intended to be the first of a series systematically describing the main platforms of the Victorian coast.

The bearing of the facts here recorded on the question of the recent emergence of the shoreline is reserved for later discussion.

General Description of the Mt. Martha Coast.

The coast-line described stretches north-westerly from the north-east corner of Dromana Bay, on the eastern side of Port Phillip Bay, to Martha Point, and thence north-easterly to just beyond Martha Cliff, which is a short distance south of the mouth of Balcombe Creek, a total distance of about three and a half miles (fig. 1).

Along this line the granodiorite dome of Mt. Martha is betrunked by cliffs, which are due to marine abrasion. The Mt. Martha dome is separated from the similar dome of Mt. Eliza to the north, and from the granite dome of Arthur's Seat to the south, by belts of low-lying country, more or less covered by recent deposits.

The Mt. Martha coast is exposed to the action of powerful waves which are developed by the strong southerly and south-westerly winds which sweep across the bay. The average range of the tide is from 2 to 3 feet.

The important aspects of the Mt. Martha granodiorite for the purposes of this paper are its system of joints and its degree of weathering at various points along the coast-line.

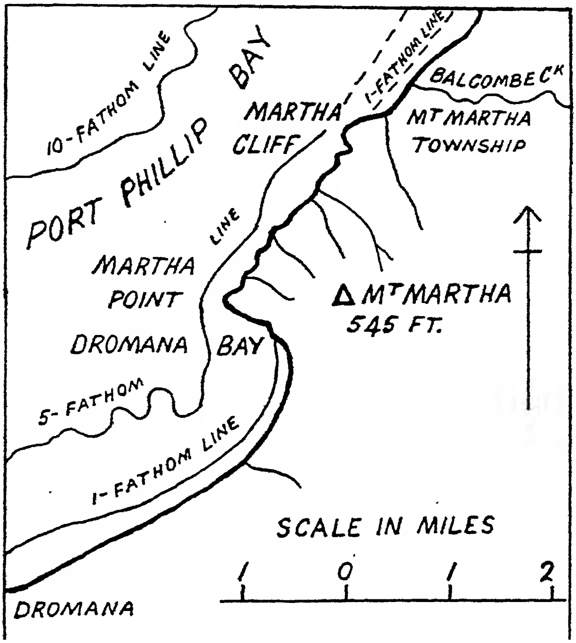

FIG. 1.—Map of the Mt. Martha coast.

The granodiorite is much and, in places, irregularly, jointed, but the strongest and most persistent joints are those which are vertical or close to the vertical. These vertical joints cut one another at various angles but two sets approximate towards a right angle.

The inner portion of the granodiorite up to varying heights above sea level (with perhaps a maximum of 30 feet, but this is a mere approximation) is a tough, practically undecomposed rock, highly resistant to erosion. The outer shell is decomposed and at each end of the outcrop, that is, to the immediate south of Balcombe Creek and just to the north of Dromana, the decomposed rock passes below sea level to an unknown depth (fig. 2). Decomposition is greatest at the extreme northern and southern ends of the rock mass.

The north-westward-trending coast (which may for convenience be termed "the southern coast") has at its south-eastern end a platform cut in decomposed granodiorite at the foot of fairly low cliffs (pl. VIII, fig. 1). This platform may be termed

"the southern platform", and is later described. North-west from the platform the cliffs steadily rise to a height of 40 or 50 feet. They are steep and, in most portions, are covered by vegetation to within 3 or 4 feet of their base. Occasionally, a rocky bare cliff 8 to 10 feet high appears, above which is the vegetated steep slope.

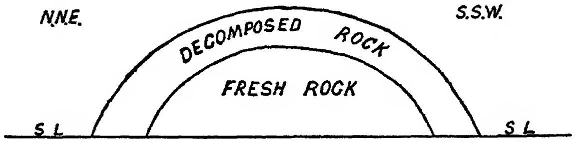

FIG. 2.—Diagrammatic section through the granodiorite dome of Mr. Martha. *S L*, sea-level.

In places at the foot of the cliffs just mentioned sharp projections or buttresses (the crests of which vary in height from approximately 2 to 10 feet above mean sea-level) of the undecomposed granodiorite occur, separated from one another by tiny bays and gulches (pl. VIII, fig. 3), the latter in some cases ending in tunnels ("caves") the position and outlines of which are generally determined by the vertical or nearly vertical joints. The gulches are up to 30 feet in length and are a few feet deep and wide. The "caves" penetrate the cliffs for about 6 feet and reach the same figure in height. The buttresses run out to sea, approximately at right angles to the coast-line, for about 30 feet and are from 4 to 20 feet wide. They have a rough outline, owing to the absence of strong horizontal joints and to the existence of close-set irregular ones in addition to the vertical master joints. The buttresses may become isolated from the cliffs and so form stacks, which in turn may be worn down to reefs.

Towards Martha Point traces only of a wave-cut rock platform are found.

In some of the small bays masses of coarse shingle, the components of which are fresh granodiorite with diameters up to 12 inches or more, are thrown up on the beach to the base of the cliffs; and similar shingle also rests in moderate quantities on the platform of decomposed rock mentioned above. In addition there are many rounded boulders of the fresh granodiorite up to 4 feet in diameter. These are either blocks broken away along joint planes with their corners rounded by the sea, or masses due to spheroidal weathering, which is well shown *in situ* at the foot of the cliffs. It may be noted that the term "shingle" is used in this paper as a general term to cover pebbles and boulders from an inch to about 18 inches in diameter.

Treating now the north-eastward-trending coast, which may be referred to as "the western coast", a platform cut in the decomposed granodiorite occurs to the south and east of Martha Cliff.

It may be termed "the northern platform". It generally resembles the southern platform, except that the steep cliffs behind it are higher than those flanking the southern platform. The remainder of this part of the coast has high cliffs composed of the fresh granodiorite in their lower portions and of decomposed granodiorite in their upper portions, the lower portions being, as a rule, steeper and with less vegetation than the upper portions.

This western coast, other than its northern end, has a crenulated outline, similar to that of the southern coast, except that the gulches are deeper, wider and longer, and the buttresses have a maximum greater width (some have been noted up to 30 feet wide) than those of the southern coast.

Shingle occurs on the western coast, usually in small quantities, in the little bays and between the buttresses (pl. VIII, fig. 2), but within a mile south of Martha Cliff there are some substantial banks. The shingle consists of fresh or somewhat decomposed granodiorite with occasional pebbles of ferruginous grit and sandstone. It also occurs, in a few instances, on the northern platform.

Along the western coast no platform in the fresh granodiorite is visible at the foot of the cliffs, except occasional patches a few square yards in area.

In their early form the buttresses have no uniformity in height, and their surfaces slope seaward at a moderate angle to the horizontal (pl. VIII. fig. 2). The occurrence of the buttresses is due to the action of the sea in creating gulches along comparatively weak areas of the fresh rocks, and to the stripping by atmospheric erosion of the softer material above the projections. This process continues until a buttress or a portion of it becomes low enough to be attacked by the sea, when it may be reduced almost to a horizontal plane and gradually lowered until it becomes a reef, which may in turn be removed by the waves (pl. VIII, fig. 4).

Progradation has taken place to a small extent in places along the southern coast.

The form of the cliffs and the abundance or scarcity of vegetation growing thereon reflect the character of their component rocks. Thus the cliffs of granodiorite decomposed to below sea-level are steep owing to the rapid undermining at their base, and are comparatively bare of vegetation on account of their steepness (pl. VIII, fig. 1). They have a young shore profile. The cliffs with fresh granodiorite at their base, and decomposed granodiorite above are steep in their lower hard portions, but moderately inclined and covered with abundant vegetation in their upper softer portions. They have a shore profile which, broadly speaking, is early mature.

The sea, even when moderately smooth, reaches the headlands and the heads of the gulches and small bays between the buttresses. In the larger bays of the southern coast, especially where banks of shingle occur, it is probable that only at rather exceptionally high tides or during storms do the waves reach the foot of the cliffs.

The cliffs less resistant to erosion with their accompanying well-developed wave-cut platforms are composed of brown rocks (decomposed granodiorite) and the more resistant cliffs, with few visible traces of wave-cut platforms, are in their lower portions, composed of grey rocks (fresh granodiorite). It will be convenient to refer to these two types in this way.

It may here be noted that the brown rocks in places at the foot of the cliffs have become somewhat tough again by the introduction of iron oxide.

The Nature and Mode of Formation of the Platforms.

THE NORMAL PLATFORMS.

The southern platform commences at the north-eastern corner of Dromana Bay, whence it runs continuously north-westerly for about 100 yards (pl. VIII, fig. 1). Thence it occurs at intervals in the same direction for some distance. Its average width is probably less than a chain and its surface, although generally very level, is broken in places by small stacks up to 8 feet high Heavy granodiorite shingle covers certain areas.

The northern platform, which lies to the east and south of Martha Cliff, is about 500 to 600 yards long and averages perhaps from a chain to one and a half chains in width. It carries small stacks a few feet high.

Both platforms are exposed at low tide, but are not covered by every high tide. They have been cut by the sea in the brown rock, in which the degree of decomposition varies, the most decomposed rocks along the coast-line occurring at the northern and southern ends of the granodiorite dome. This feature is reflected in the surface character of the platforms, in that the more decomposed the rock, the smoother the platform. This is especially noticeable in the northern platform where, at its southern end, there are pronounced irregularities—both major and minor—on its surface. These gradually decrease northward until, where the platform runs east from Martha Cliff, most of the major projections are smoothed away and only very minor ones remain. These minor ones, however, make in parts an unusually irregular platform surface within low vertical limits. To a less extent, the same features are repeated on the southern platform. No "rampart" similar to that described by C. K. Wentworth (2) occurs at the outer edge of either platform.

Where the granodiorite is thoroughly decomposed at the extreme southern end of the dome, the rocks are so easily removed that a platform is cut at a lower level than the normal platforms here described, and becomes covered with detritus.

The platforms are practically horizontal (pl. VIII, fig. 1) except, in places, for a width of a few yards at the base of the cliffs, whence they slope seaward at angles varying from about 5° to 8° similarly to the ordinary sandy beach. This is a common feature in most of the Australian platforms that the writer has examined. As the platform advances landward this sloping area will be planed down to the general level, but a new narrow area slightly inclined seaward will be formed immediately in front of the cliffs as the latter retreat landward. This narrow sloping strip coincides with Wentworth's "abrasion ramp" (2) and is due to wave planation.

At their landward edges the platforms are flanked by moderately high, steep cliffs of the brown rock and at their seaward edges the platforms descend sharply into the sea to a depth of from 4 to 10 feet, according to the distance any particular portion of the edge is from the high tide shoreline (fig. 3). (The sea bottom off the edge of the normal platforms is part of what is later described as the "ultimate platform"). The seaward edges of the surfaces of the platforms are very uneven, owing to the action of the waves in locating differences of resistance to erosion in the component rocks.

In the production of the normal platform, the comparative softness of the rocks nullifies the effect of geological structure and enables the sea to produce a platform with a relatively smooth surface exposed between tide marks (pl. VIII, fig. 1).

The normal platforms are constantly being extended landward by abrasion by the sea at the foot of the cliffs, and are constantly being destroyed at their seaward edges by the sea's attack (fig. 4). For a platform to exist, the rate of advance landward must at some period have been greater than the rate of destruction seaward. Once, however, the platform is established, it may widen or narrow, or eventually disappear altogether, according to the lithological nature and geological structure of the rocks at various points. Thus, if the component rocks of the cliffs changed from "soft" to "hard" rocks, erosion (other things being equal) would slow down and the rate of advance be retarded, and if at the same time the outer portion of the platform were or became composed of "soft" rocks, the rate of erosion would be either actually or relatively increased, with the result that the platform would become narrower. Conversely, if the component rocks of the cliffs became less resistant to erosion and the rocks at the seaward edge were or became more resistant to erosion, the rate of advance would be accelerated and the platform would widen. Further changes in the respective rates of

erosion would bring about further changes in the width of the platform, with the possibility always of its disappearance and later re-birth. Alteration in the geological structure of the rocks and other factors, such as changes in the direction or power of the waves, might also check or hasten the growth of the platform.

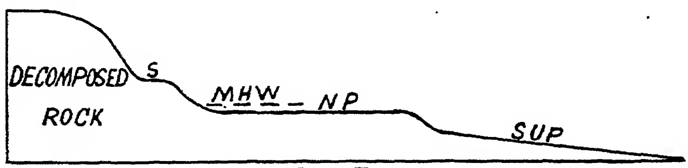

Fig. 3

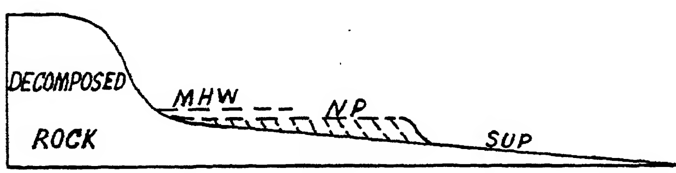

Fig. 4

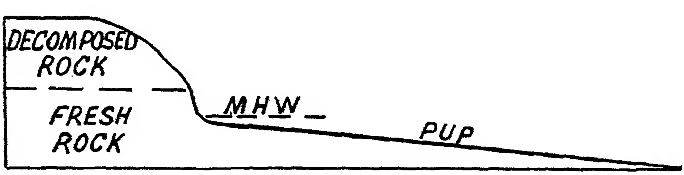

Fig. 5

FIG. 3.—Diagrammatic section showing the shelf, *S*; the normal platform, *N P*; the secondary ultimate platform, *S U P*; and the steep cliff, all in the decomposed rock. *M H W*, mean high-water level.

FIG. 4.—Diagrammatic section showing the removal by marine abrasion of the normal platform, *N P*; the extension thereby of the secondary ultimate platform, *S U P*, to the steep cliff, all in the decomposed rock. *M H W*, mean high-water level.

FIG. 5.—Diagrammatic section showing the formation in the fresh rock of the primary ultimate platform, *P U P*; the short steep cliff in the lower fresh rock; and the comparatively gentle slope of the cliff in the upper decomposed rock. *M H W*, mean high-water level.

It might be noted that exposure of the rocks at low tide will, to some extent, bring about their alternate wetting and part drying, which may aid in the disintegration of the rocks and thus facilitate their removal by the waves. This process however does not fulfil the conditions of water-levelling, including the presence of an outer rampart, as laid down by Wentworth (2). Since also the platforms are not solution benches (Wentworth (3)),

wave planation is regarded as the dominant factor not only in the production of the abrasion ramps, but of the normal platforms as a whole.

THE ULTIMATE PLATFORM.

The ultimate platform, as here defined, is that rock bench which is almost entirely hidden from direct observation being, except at its extreme landward edge, generally covered by the sea, even at low water (pl. VIII, figs. 2, 3, 4). It appears to have a fairly rapid fall seaward, and is thus in marked contrast with the normal platform. In fact, it resembles the platform figured in nearly every geological text-book, although, so far as the immediate vicinity of the shore is concerned, it is probably the exception rather than the rule.

The ultimate platform has two aspects: First, as a primary platform, in that a normal platform has apparently never preceded its formation (fig. 5). Secondly, as a secondary platform in that the normal platform is first cut and the ultimate platform results from the destruction of the normal platform (figs. 3 and 4). These two aspects will be separately dealt with.

The ultimate platform as a primary platform.—This platform occurs off the middle portion of the Mt. Martha coastline, where the grey rock occurs at sea-level and for some height above it, and where there is no development of the normal platform.

Observation shows that the sea does not wear down the grey rock to a smooth plane, inclined or horizontal. The process by which destruction takes place may be described as quarrying (pl. VIII, fig. 2). The sea, armed with detritus, erodes channels along the strong vertical or nearly vertical joints and the channels gradually lengthen, widen and deepen. There are numerous, moderately widely spaced cross joints, either inclined at various angles or approximately horizontal; many close-set irregular joints also occur, these joints in some instances being not more than 3 inches apart. When the sea has worked along the vertical joints for some time, a block, from 2 or more feet to 3 inches across in any direction, can be dislodged by a violent blow of the waves, or by gradual undermining. The dislodged block is then further attacked and is eventually removed as shingle or sand. The result is that the surface of the grey rock tends to be irregular, especially in view of the fact that there is no system of strong horizontal joints.

There must be lines of weakness in the grey rock, although the latter appears to be homogeneous, since the sea acts selectively in cutting the deep and wide gulches between the buttresses as already described.

These processes therefore militate against the formation of an even-surfaced platform exposed at low tide, except in very limited areas, as, for example, at the foot of the cliffs in the small bays and between the buttresses, where such surfaces, sloping upward to the cliffs at angles of from 5° to 8°, occur, and form abrasion ramps. Similar surfaces of small area can be seen under water at low tide (though even these surfaces are marked by sand and shingle). The sea, however, is encroaching on to the cliffs and therefore a platform is being cut which is not open to direct observation, and the surface of which may be very irregular. Since also the sea-bottom gradually deepens, the platform must have a steady fall seaward and extend in that direction, but how far, will depend on the position of the shoreline at the commencement of the present cycle of marine abrasion. Whether the platform is free from, or covered by, detritus is at present unknown. Doubtless both conditions occur. Probably also, on the whole, the platform is being steadily degraded.

The retreat of the cliffs is slow compared with that of the cliffs flanking the normal platforms. This gives the sea time to cut more deeply, and so form the primary ultimate platform without the production of the normal platform as a temporary feature.

The ultimate platform as a secondary platform.—This class of platform is formed by the abrasion by the sea at a lower level than the normal platform (figs. 3 and 4), and with apparently a steady fall seaward similar to that of the primary ultimate platform. The difference between the two types of the ultimate platform is that the primary platform is cut in the grey rock without any relation to the normal platform, whereas the secondary platform is cut in the brown rock subsequently to the formation and results from the destruction of the normal platform.

Usually the secondary ultimate platform on its landward side abuts against the low cliff at the seaward edge of the normal platform, which the sea is constantly cutting away. In this manner the secondary ultimate platform grows landward. So long as the rate of advance of the normal platform at its landward edge is equal to or greater than the rate of destruction of the same platform at its seaward edge, the normal platform will intervene between the cliffs and the secondary ultimate platform. If, however, the converse happens, then the normal platform will disappear and the secondary ultimate platform will reach the shore (fig. 4). This has happened to the northern normal platform in some tiny bays where the conditions to ensure such a result have been favourable. In that case the secondary ultimate platform will generally resemble the primary one, except that possibly the surface below water of the former will be smoother than that of the latter.

The manner in which the normal platform may be widened, narrowed, totally destroyed and re-born is outlined above under the heading of the normal platforms.

Shelves above the Normal Platforms.

Towards the southern end of the northern normal platform there are a few short shelves a few feet wide rising to 8 feet above that platform (fig. 3). They are free from detritus (although above the shelves detritus occurs on the cliff face and the ledges projecting therefrom) thereby indicating the fact that the sea, by waves or spray, reaches these shelves and, by the removal of the debris formed by atmospheric erosion and perhaps even by direct abrasion, is mainly responsible for the occurrence of the shelves. That the spray reaches the shelves is shown by the presence of living marine mollusca there, as well as by direct observation.

Summary.

At the northern and southern ends of the granodiorite dome of Mt. Martha the rock at the coast-line is decomposed ("soft") but between these outcrops it is fresh ("hard").

An almost horizontal platform (the normal platform) cut in the soft rocks at each extremity and backed by steep cliffs of the same class of rock, is exposed at low tide.

The coast-line of the hard rocks is broken into a series of tiny bays and gulches, between which are pronounced buttresses. A platform cut in this hard rock by the waves slopes steadily seaward and its fall is so comparatively rapid that, except at the heads of the small bays and gulches just mentioned, it is not exposed at low tide, thus offering a marked contrast with the normal platform. It coincides with the wave-cut platform of the text books[*] and, since it appears to be both an original and (as regards the present cycle of erosion) a final form, subject to its gradual lowering if not protected by marine deposits, it is termed a primary ultimate platform.

The normal platform, although it is advancing at its landward edge, yet is being destroyed at its seaward edge, and another platform, due to such destruction, is being cut in the soft rocks at a lower level and appears to slope steadily seaward. This lower platform is another type of the ultimate platform but, since it is of secondary origin, it is termed a secondary ultimate platform.

The decomposed rocks favour the formation of a coast-line, mostly smooth in outline; of the normal and secondary ultimate platforms; and of steep cliffs with scanty vegetation. Geological structure has apparently little influence on the making of those features. On the other hand, the hard rocks and their geological

structure favour the formation of the contrasted crenulated coastline; of the primary ultimate platform; and, except in their lower portions, of sloping cliffs with abundant vegetation.

The normal platforms are due to wave planation, and the ultimate platforms to the quarrying action of the sea and wave planation combined.

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Explanation of the Plate.

PLATE VIII.

FIG. 1.—The north-east corner of Dromana Bay. The normal platform and the steep cliffs, all cut in the decomposed granodiorite.

FIG. 2.—South of Martha Cliff. The sloping vegetation-covered cliffs; the buttresses of fresh granodiorite, with the alternating gulches at the foot of the cliffs; and the small bay, with shingle covering a strip of the primary ultimate platform, which rapidly falls beneath the sea.

FIG. 3.—East of Martha Point. A succession of buttresses, planed almost level by the sea, and gulches in the fresh granodiorite, being transient features in the formation of the primary ultimate platform.

FIG. 4.—South of Martha Cliff. A further stage in the formation of the primary ultimate platform. The buttresses of fresh granodiorite are mostly reduced to small reefs.

[Proc. Roy. Soc. Victoria, 52 (N.S.), Pt. I., 1940.]

Art. X.—*Soil and Land Utilization Survey of the Country Around Berwick.*

By L. C. HOLMES, B.Agr.Sc., G. W. LEEPER, M.Sc., and K. D. NICOLLS, B.Agr.Sc.

[Read 13th April, 1939; issued separately, 1st March, 1940.]

Contents.

I. Introduction.

The object of the work reported here has been to obtain exact information concerning the potentialities and the present use of the land in a section of the coastal strip of south-eastern Australia in which rainfall is seldom seriously deficient. The provision of money from the University of Melbourne's Commonwealth Research Fund in 1937-38 made it possible to carry out a detailed study of a sample area in such country.

The area chosen for this survey covers 59 square miles and is centred approximately around Berwick, which is 27 miles east of Melbourne. Its boundaries do not coincide with those of a parish or shire, but were chosen in order to include representative portions of non-agricultural rugged hills, gentler foothills, and undulating to flat land. The general level of natural fertility in this area is low, though there are some fertile patches. The mean annual rainfall is 30 inches, increasing to 40 on the higher hills, and is fairly well distributed through the year. In all these respects the district is typical of Gippsland as a whole, although for statistical purposes it is included in the Central District, and lies just west of the boundary of Gippsland.

The survey consists of two main sections, namely, the mapping of soil types and the collection of information from the individual farmers as to their activities. For the latter purpose, questionnaire sheets were drawn up to deal with each of the main occupations. Circulars were first sent to all farmers with a holding of more than 20 acres, explaining the object and nature of the inquiry. Each of these farmers was later visited and the soils on his property were mapped. The information has been so tabulated that no details of any individual farmer's activities are disclosed.

The project was greatly facilitated through the kindness of the Royal Australian Air Force in providing us with aerial photographs at the scale of 4 inches to the mile. The individual contact prints, measuring 7 inches square and covering 1,980 acres, proved invaluable in the field in providing reference points for mapping and in indicating boundaries of properties and of soil types; these prints were also very helpful in arousing the interest of many of the farmers. We should like to record here our gratitude to the Royal Australian Air Force.

II. Description of the Surveyed Area.

The location of the area is shown in fig. 1, together with the railways and chief towns in the neighbourhood. Dandenong, with over 4,000 inhabitants, is the largest town in the neighbourhood and is one of the most important markets for livestock in the State. It is the terminus of a suburban electric-train service from Melbourne. The surveyed area was chosen with the idea that it was far enough away from the metropolis to be free from any suburban characters; though this is not quite correct, it is approximately true. The area is typically rural; the only factory in the district is one at Officer, at which building tiles and pipes for agricultural drains are made.

Topography.

The surveyed area may be divided into two portions, lying north and south of the main road from Melbourne to Sale (the Princes Highway). This coincides roughly with the 200-foot contour (as shown on the Military Survey).

The land to the north of the highway is hilly, and constitutes the south-western extremity of the great mountain chain of eastern Victoria; the highest point within our area is Upper Beaconsfield (700 feet), and the 1,000-ft. contour lies 5 miles away to the north. The hills to the east of Cardinia Creek are fairly steep, slopes of 14 degrees being frequent. West of Cardinia Creek the round-topped hills of basalt are the dominant feature. Slopes are generally gentler here, and the highest point, west of Harkaway, is 550 feet, from which the country falls away sharply to the west.

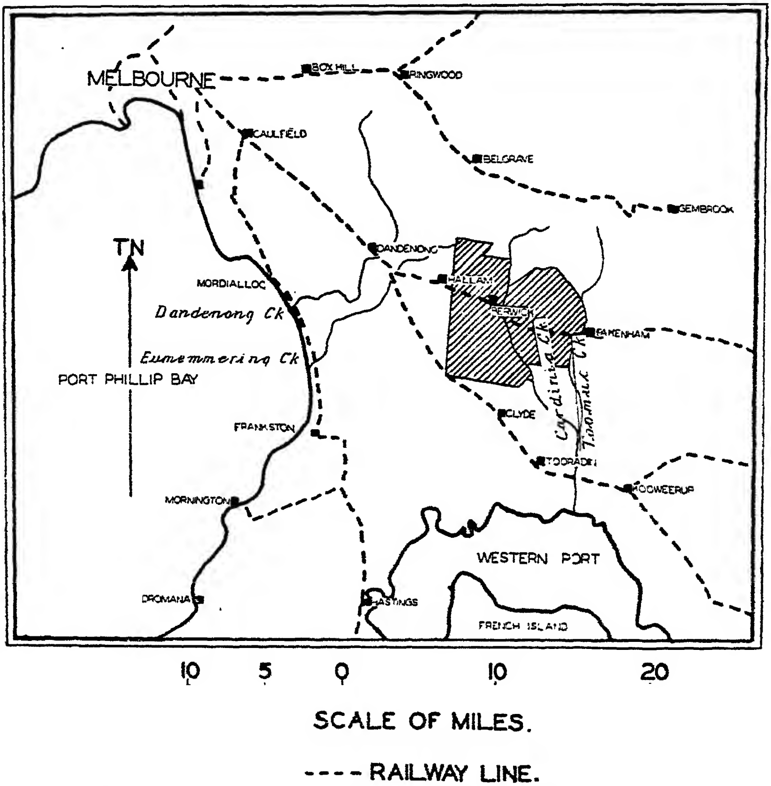


Fig. 1.—Position of surveyed area relative to surrounding country.

The land to the south of the highway is gently undulating or flat, except for a few hills near Berwick, and the 200-ft. contour comes south of the road at only a few points. The 50-ft. contour includes the south-eastern corner of the area, and from here to the coast of Westernport Bay (9 miles away) the land is very flat. This country to the south-east of our area is the great basin of Koo-wee-rup, formerly a swamp and now reclaimed by means of a network of drains and embankments.

Natural Drainage.

Cardinia Creek and Toomuc Creek, which rise about 5 miles away to the north, are the only well-defined streams. Little water runs in them in summer and autumn, but their flow does not cease altogether except in the severest drought. Further to the south the two creeks join and the water flows through one of the major drains of the Koo-wee-rup scheme into Westernport Bay.

The western part of the area drains by the Eumemmering Creek into Port Phillip Bay. Hallam Valley, lying just south of Berwick and Narre Warren, collects water which joins the Eumemmering 4 miles to the west of Narre Warren. The divide between these two systems is defined by the ridge of basalt coming through Harkaway and Berwick to the south of Beaconsfield, and then swinging south-west to Cranbourne.

There are numerous minor watercourses, most of which are artificial and have been cut in order to drain swampy patches. Many of these have scoured, even in very gently sloping country. Toomuc Creek itself provides a striking example. This creek formerly spread over flat country near its present course with no defined bed, and the present narrow course from the point where the main road crosses it has been scoured out since the land was settled, having been started, according to tradition, by a furrow that was scooped out for the purpose of drainage. Even more spectacular ravines have been scoured out at the foot of the hills north from Narre Warren (see pl. X, fig. 3). In one property a straight drain was cut in the early days of settlement and a gully has now been formed 30 feet deep and over half a mile long, bisecting the farmer's property. The rapid run-off of water from the deforested hills around has probably contributed to this effect.

Geology.

Kitson's rapid survey (1) in 1901 of the country around Berwick is the only account of the geology of this district, except for a note (2) on the unimportant gold mining in Haunted Gully, where the reservoir now lies for the supply of water to Mornington Peninsula. The geological boundaries as defined in the present survey are shown in fig. 2.

The geological history of the district is as follows. The bedrock consists of folded and compressed Silurian marine mudstones which are soft where they are exposed. In the Devonian age there was an intrusion of granodiorite below the surface of the Silurian bedrock. This granodiorite has since been exposed in places in the north (such as Harkaway) by the erosion of the Silurian rocks. In Oligocene or Lower Miocene times streams of basaltic lava started near the northern fringe of the area and flowed through the valleys, moving first south and then south-west through Cranbourne. The present surface of this flow is 600 feet above sea-level just north of Harkaway, 300 feet at Berwick township, and 100 feet at Cranbourne, after which it is lost below the present level of the land. There were at least two flows of this basalt, the later flow being denser (3); they are

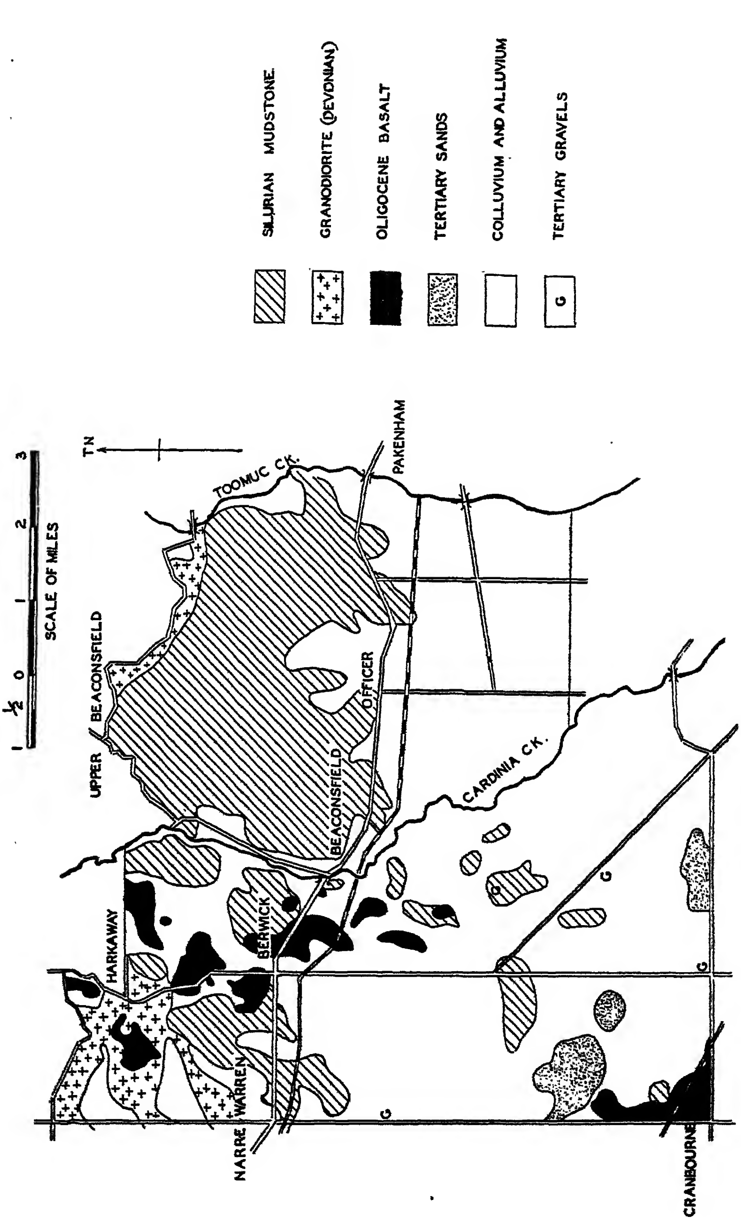


Fig. 2.—Geological Map of Berwick Area.

separated or covered by a sandy sediment in a few places giving rise to some curious mixed soil profiles in which the upper and lower layers are developed from different materials. There is a good example at the northern end of Wilson's quarry at Berwick. Here a foot of light-grey sandy loam which could not have been formed from basalt overlies the material derived from the lower flow of basalt.

The Silurian rocks have been eroded more rapidly than the basalt, with the result that the basalt which once filled the valley now stands out as smooth hills with rather steep sides. At some places, such as the town of Berwick itself, the process has reached the stage where the Silurian rock and the basalt are on about the same level. Near Harkaway the basalt rests on granodiorite, and here also is a ridge with both rocks on the same level.

The flat and undulating country to the south of the highway is formed of material brought down from the granodiorite and from the Silurian rocks. Frequent changes in course and in the fineness of the material carried by former creeks have resulted in the high variability of the soil to-day over much of this southern country. A few gentle hills of Silurian rock remain uncovered, dotted here and there over the plain. The land has been mapped as "colluvium" wherever there is no rock within 6 feet of the surface.

Definite remnants of Tertiary river-beds occur at a few places; there are two groups of these, a deep sand and a gravelly clay. Both of these deposits are quarried for local use. The so-called gravel beds are used for road-making, but are undesirably high in clay for the purpose. We have not attempted to map the boundaries of these gravelly deposits accurately, but have merely marked the sites of gravel pits. It is possible that some of the land marked on the soil map as "Toomuc sandy loam" is derived from the same Tertiary deposits.

III. Climate.

Total Annual Rainfall.

The mean annual rainfall over the country south of the highway is close to 30 inches. There are no stations within this area which send in daily reports to the weather bureau at Melbourne, but monthly records have been kept since 1887 by the Patterson family, now at "Jesmond Dene," Cardinia Creek (4). The average here to the end of 1937 is 31.55 inches. We have also used the figures which have been either taken from (4) or supplied from personal records by the courtesy of local residents, for several other places, including Narre Warren, Berwick, Pakenham, Cranbourne, and Clyde. Some of these records extend over too short a period to calculate a reliable average, but if the figures are compared with those for the same years at "Jesmond Dene,"

and it is assumed that the mean ratio of the rainfall of each station to that of "Jesmond Dene" remains steady, it appears that all these stations have between 28.5 and 30.5 inches. A rainfall of about 30 inches is the rule in the flatter country within 25 miles east of Port Phillip Bay, and the excess of rain over that falling at Melbourne (average 25.6 inches) is probably due to the moisture carried by westerly and south-westerly winds which have recently passed over water.

The annual rainfall at "Jesmond Dene" has ranged from 46.54 inches in 1924 to 18.39 inches in 1908. The median rainfall is 31.25 inches. The mean deviation of all years from this median is 4.45 inches or 14 per cent.

North of the highway, rainfall increases sharply with altitude. Upper Beaconsfield, 700 feet high, with 38.5 inches, is typical of the higher land within the surveyed area, and the orchards in the foothills above Officer probably receive about 33 inches.

Distribution and Effectiveness of the Rain.

The value of a given annual rainfall naturally depends on its monthly distribution. The monthly averages for "Jesmond Dene" are given in Table I. Temperature and evaporation are not recorded in this district, but the mean figures for Melbourne must be close to the local values and they are therefore incorporated in the table.

Table I.—Mean Monthly Rainfall from 1887 to 1937 at "Jesmond Dene," Cardinia Creek, and Mean Figures for Temperature and Evaporation at Melbourne.

—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Rain ..	214	159	257	288	270	277	271	279	298	328	249	265	3,155
Temp. ..	67·4	67·6	64·6	59·4	54·1	50·4	48·8	51·0	54·1	57·7	61·3	64·9	58·4
Evap. ..	643	504	401	241	149	113	109	150	232	336	454	574	3,905

Rain and evaporation are recorded in "points" of one hundredth of an inch.

Although at first sight it appears that the rainfall is evenly distributed, the year is in fact divided into a wet season (winter and early spring) and a dry season (summer and early autumn). The climate has some of the character of the Mediterranean type of dry summer and wet winter, but differs from it in the extension of the rainy season well into the spring and in the occurrence of erratic storms of tropical origin which particularly favour the eastern half of Victoria during the summer and early autumn. Apart from these irregular tropical spells, the summer is typically

dry and sunny, with occasional bouts of hot north winds blowing from the arid interior, which contribute to the high evaporation. The liability to dry spells may best be seen from Table II, in which the median rainfall is tabulated instead of the mean. Since

TABLE II.—VARIABILITY OF MONTHLY RAINFALL AT "JESMOND DENE," 1887-1937.

—	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Median rainfall ..	168	104	215	263	255	273	261	270	272	323	222	250
Mean deviation from median ..	125	105	135	146	95	96	90	88	92	124	109	122
Percentage deviation	74	·101	63	55	37	35	34	33	34	38	49	49
No. of times month's rain fell below 1 inch ..	14	22	12	6	3	3	3	0	1	3	7	9

the chances are equal that in any year or month the rain will be below the median, it is a more informative figure than the arithmetical mean, which may be compounded from several dry months and a few very wet ones. This table demonstrates the high reliability of the rain during the six cooler months, May to October, whether one considers the percentage variability or the possibility of a total of less than 1 inch. Fig. 3 illustrates the most important material in Tables I and II. The high reliability of rain in spring is especially important, since the temperature is then high enough for rapid growth. In fact, from 1885 to 1937 the combined rainfall in September and October had only three times fallen below 3½ inches, viz., in 1888, 1896, and 1914. In 1938 the figure was only 173 points, and since the autumn of 1938 was also abnormally hot and dry, this year stands out as the worst since records were taken.

Summer rainfall is arratic and is generally too low to be of much use to plants except in abnormally wet years, in which the growth of pastures is prolonged well into the summer. If we use Trumble's principle (5) that the moisture in the soil falls below the point at which plants permanently wilt when the ratio of rainfall to evaporation (P/E) is less than one-third, then in 29 summers out of 50 there were at least two successive months too dry for growth. Or taking the arbitrary standard that a month with P/E less than one-half is dry, there were 30 summers with at least three such dry months in succession. In spite of this, summer-growing forage crops—especially maize and millet—are widely used. These are sown in late spring, when rainfall is relatively reliable, and they grow on the moisture conserved in the wetter months. The more clayey soils of the depressions naturally hold greater reserves of water, so that they can be

used relatively safely for summer crops without gambling on the weather. Possibly the maize plants on some of the depressions get their roots within reach of permanent water.

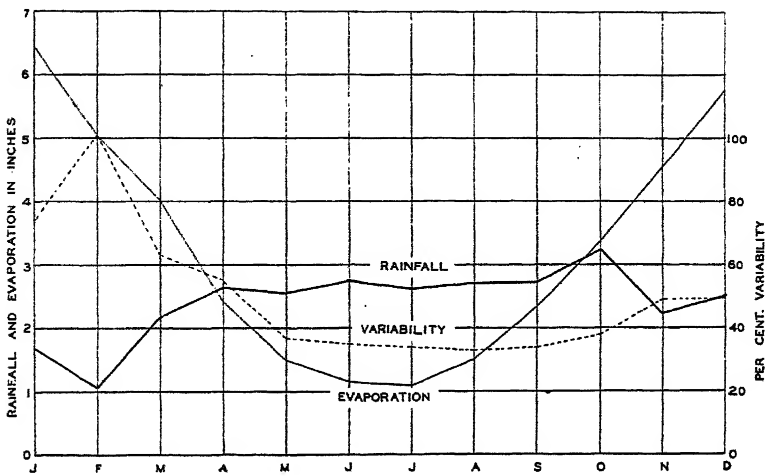


FIG. 3.—Median monthly rainfall, showing also percentage variability and mean evaporation.

Pastures are however far more important here than crops, and the most valuable constituents of the pastures are subterranean clover and perennial rye grass. With regard to these, the most important among the more variable factors in the weather is the "break of the season" in autumn—that is, the date after which the soil does not dry out until the following summer. This "break" may occur at any time from early March to mid May, and the earlier date is highly desirable, since rain coming while the soil is warm allows the annual plants to become well established.

Much the same general considerations apply to the settled hilly country for about 2 miles to the north of the highway as to the flatter country to the south. These foothills receive 10 to 20 per cent. more rain, and presumably lose less water by evaporation. The natural rainfall, however, is often too little for the orchards during the summer, and many orchardists irrigate their trees.

During June, July, and August frosts are not severe, and in the majority of winters the air temperature never falls below freezing-point. However, the mean temperature of the soil, again using the Melbourne records, is between 45° and 50°F.,

and this is too low for rapid growth. During winter and early spring there is no lack of rain; on the contrary, there is often an excess, and the saturation of the soil helps to keep growth at a low rate. The subsoils consist generally of relatively impermeable clay, and it is likely that drainage is a limiting factor to growth throughout the district. The effect of the cold period in winter is well shown in the very low figures for the growth of pastures for almost all stations in Southern Victoria which have been recorded by the Victorian Pasture Improvement League and published from time to time in the Journal of the Department of Agriculture of Victoria. The local conception of a "good winter" is one with rain below the average, and therefore with a minimum of water-logging.

IV. Description of Soil Types.

The basis of the classification and mapping of the soils (see fig. 6) is the *profile*—that is, the set of characteristics which one observes in the face of a pit, or occasionally in a roadside cutting. Such a profile consists of a succession of layers, known as horizons, differing from one another in texture and colour, and other less obvious features. Each "soil type" is known by a place-name and a term which describes the texture of the surface soil. The same place-name may be attached to two types if they are closely related to each other.

The soil types described in this section fall into four main groups, namely:—

Podzolic types,
Heavier soils on low-lying land,
Soils developed on basalt,
Miscellaneous, unnamed types.

Podzolic Types.

The predominant tendency among soils both in the surveyed area and in Gippsland is to develop a profile with the characteristics of a "podzol." A "podzol" develops typically in regions of fairly heavy winter rainfall; it has a low reserve of calcium, magnesium, and potassium, which have been washed away with drainage water, and consequently it is definitely acidic. Its reserve of phosphate is similarly low. Physically, much of the finest material has been removed from the upper layers and concentrated at lower depths, so that the sandy surface contrasts sharply with a clayey subsoil. Further, the downward movement of iron compounds has left the surface grey, and has

given the subsoil a yellow shade. Some podzols are also marked by a particularly light colour just below the surface (see pl. X). The colour and texture of the five podzolic types of this district are illustrated in fig. 4.

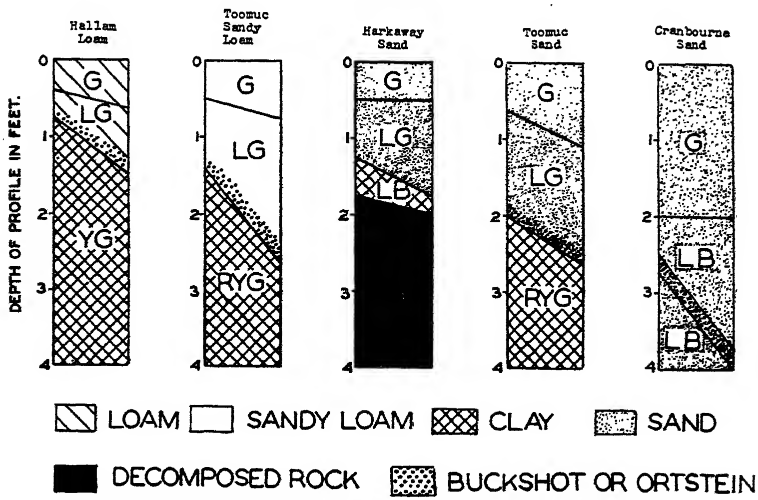


Fig. 4.—Profiles of five Podzolic soil types. Letters stand for colours as follows:—B, brown; G, grey; L, light; R, red; Y, yellow.

1. *Harkaway Sand.* (See also pl. X, fig. 2.)

This type is found on the granodiorite in the hilly country to the north. Boulders several feet across occupy some of the land, but in many places the soil is deep; this combination of boulders with deep soil is commonly found in country developed from granite or granodiorite. The typical profile is as follows:—

Horizon 1. (0–6 inches)—Grey loamy sand or sandy loam.

Horizon 2. (6–18 inches)—Light-grey sand. Soft concretions containing iron oxide and organic matter may occur near the bottom of this sandy horizon.

Horizon 3. (18–24 inches)—Sandy clay, often with a greasy feel due to mica. The colour is a mottling of grey, yellow, and red, with red predominating.

Horizon 4. (24 inches downwards)—This sandy clay grades imperceptibly into decomposing rock, in which the amount of clay gradually diminishes with depth as a smaller proportion of clay-forming minerals are decomposed.

The transition from Horizon 2 to 3 is very sharp, and may take place at any depth from 15 to 21 inches. This marked difference between surface and subsoil is usually a sign that the soil is highly mature—implying, in this case, that the rain has already washed away the reserves of valuable elements.

However, the persistence of small grains of hornblende and other primary minerals in the surface layers, as revealed by microscopic examination of the "fine sand" fraction, is a redeeming feature of these soils, and the analysis of a single sample indicates that this type is better provided with potassium than the other light types of the district.

2. *Cranbourne Sand.*

This is found especially in the south-west of the area. It has been developed on deep sand deposited by rivers in Tertiary times, the original source of the quartz sand being the granodiorite from the hills to the north. It is likely that this sand has been affected by wind-blowing since it was laid down. The typical profile is as follows:—

Horizon 1. (0–23 inches)—Grey loose sand, becoming lighter in colour below about 9 inches.

Horizon 2. (23–46 inches)—Light-brown sand.

Horizon 3. (46–48 inches)—Dark-brown cemented layer. This consists of sand cemented together by organic matter and other material washed down in colloidal solution. It is described in other countries by the German term "Ortstein", and is locally known as "coffee-rock".

Horizon 4. (48–78 inches)—Sand containing small nodules of clay. Though the percentage of clay is very low, its presence is obvious to the feel. This layer is often wet. In many places the sand extends to a depth of many feet.

The vegetation of this type (see p. 236) is characteristic. It has been left uncleared longer than any other type on the south of the main road, since it is chemically very poor, and is so sandy that it retains very little water as a reserve against drought.

3. *Toomuc Sand.*

This soil has developed on mixed colluvial material derived from granodiorite and Silurian mudstone. It occurs mainly as small ridges 1 foot or more above the level of Toomuc sandy loam, a more important type with which it is usually associated.

The following is a typical profile:—

Horizon 1. (0–10 inches)—Grey loose sand, becoming lighter in colour with depth.

Horizon 2. (10–31 inches)—Light-grey sand, sometimes with a brownish colour.

Horizon 3. (31–33 inches)—Ironstone gravel or continuous ortstein ("coffee rock") rests on the top of the clay.

Horizon 4. (33 inches downwards)—Sandy clay, grey with red and yellow mottling, persisting to a depth of several feet.

Rushes grow on many patches of this type, giving evidence that underdrainage is particularly poor.

4. *Toomuc Sandy Loam.*

This has also developed on the material washed down from the hills, or in some cases from Tertiary sediments that have been consolidated to form ridges of sandy or gravelly clay. The typical profile is as follows:—

Horizon 1. (0–6 inches)—Grey or light-grey sandy loam.

Horizon 2. (6–24 inches)—Very light-grey sandy loam or sand. Concretions of ironstone gravel are common at the bottom of this layer. In wet weather this layer becomes a semi-fluid mass and animals or machinery may sink deep into it. This is an example of the popularly termed "spewy" soil.

Horizon 3. (24–46 inches)—Light to medium clay, mottled yellow and grey, with red mottling increasing with depth.

Horizon 4. (46 inches downwards)—Light red-brown heavy clay.

The transition between horizons 2 and 3 is sharp. The depth at which clay occurs is normally between 20 and 26 inches, but it may be as little as 17 inches. Every transitional stage between this type and the next one (Hallam loam) occurs in the field. It shares with Hallam loam the unpleasant property of readily forming very hard clods.

5. *Hallam Loam.*

This type is formed on the material washed from the hills on to the lower, gentle slopes. Most of this material is derived from Silurian hills. The following is a typical profile:—

Horizon 1. (0–6 inches)—Grey or light-grey loam, with a floury feel due to its high content of silt. Liable to set very hard after rain.

Horizon 2. (6–13 inches)—Light-grey loam, or silty loam. This is quite structureless and is like the sub-surface of Toomuc sandy loam. Charcoal is very common in this horizon.

Horizon 3. (13–16 inches)—Light brownish-grey clay loam. Concretions of ironstone are characteristically but not invariably present. The presence of concretions at this level is doubtless due to the frequently semi-fluid nature of the surface layers through which the ironstone sinks, till it rests above the clay.

Horizon 4. (16–30 inches)—Greyish-brown heavy clay, only slowly permeable to water.

Horizon 5. (30 inches downwards)—Heavy clay with red, yellow and grey mottling.

The clay may continue for many feet, merging gradually into decomposed Silurian rock. As with the Toomuc types, the contrast between the grey loam at the surface and the yellowish clay of the subsoil is very marked, and the transitional layer (Horizon 3) is often absent. The frequent ironstone gravel, which is up to half an inch in diameter, bears witness to the fact that drainage has periodically been very slow and the subsurface waterlogged. The depth of the impermeable clay layer is usually 12-16 inches, but may be found anywhere between 9 and 20 inches.

5. (*a*) *Hallam Loam* (*Silurian Phase*). (See pl. X, fig. 1.)

There is little essential difference between the soils formed directly on the Silurian rock and those formed on the wash from the hills. In all cases there is a high percentage of silt throughout the profile, and a transition at a depth of about 1 foot from a grey silty loam to a yellowish-grey impermeable clay. Where

the rock occurs within 6 feet of the surface we have mapped the soil as the "Silurian Phase." Most of the country so mapped has rock within 3 or 4 feet of the surface. This naturally occurs on the top and the upper slopes of hills. The layer of gravel lying above the subsoil clay consists partly of smooth ironstone grains, many of which are nearly spherical, and partly of long yellowish flakes of siliceous material, presumably fragments of parent rock, cemented by iron compounds and so made resistant to weathering.

The weathered Silurian rock has a remarkably yellow colour, and this shade is characteristic also of the subsoils of this phase.

5. (*b*) *Rugged Silurian Country*.

The surface of Hallam loam is easily converted by rain into an amorphous semi-fluid mass, which is particularly liable to sheet erosion. Consequently, the depth of surface soil is much less on the steeper slopes, and only shallow, rocky soils occur in the northern country where slopes of about 14 degrees are common. Such soils are non-agricultural, and have been mapped as a separate type.

HEAVIER SOILS ON LOW-LYING LAND. (See fig. 5.)

The two types that come under this heading contain more clay than those just described, and consequently do not show any marked contrast of light surface and heavy subsoil. They occur on low-lying land, and it is clear that they have been continually receiving fine material that has been washed down from the higher land around them. Thus they not only differ from the podzolic soils in the absence of contrast between the surface and subsoil and by their waterlogging for long periods, but the method of their formation also gives them a quality of relative immaturity. The natural vegetation is swamp tea-tree, and several strips of this still remain.

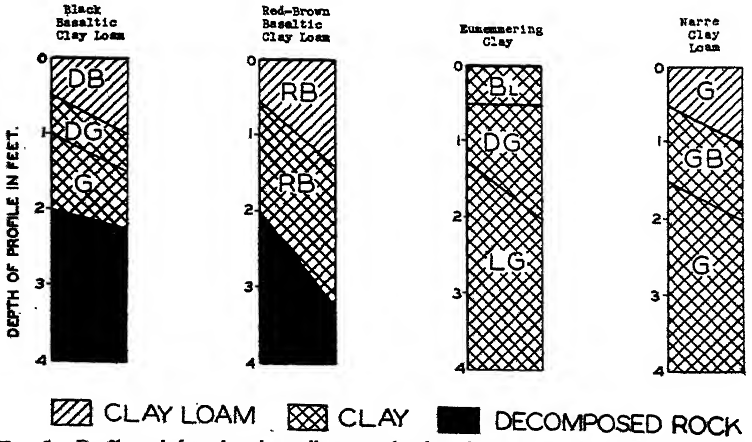


FIG. 5.—Profiles of four heavier soil types showing the colour and range in depth of the various horizons. Letters stand for colours as follows:—B, brown; BL, black; G, grey; D, dark; L, light; R, red.

6. *Narre Clay Loam.*

This occurs in depressions, often as long tongues corresponding to drainage lines, among the lighter types in the country to the south.

The following profile is typical:—

Horizon 1. (0–9 inches)—Grey clay loam with brown mottling.

Horizon 2. (9–18 inches)—Grey light clay with brown mottling.

Horizon 3. (18–31 inches)—Grey clay.

Horizon 4. (31 inches downwards)—Clay, mottled with grey, yellow and red, extending for several feet.

It is characteristic that light clay occurs at a depth less than 12 inches. The brown mottling of the surface soil is characteristic, and indicates the conditions of poor drainage under which the soil has been developed; the alternate reduction of iron compounds during periods of waterlogging and their oxidation during dry spells has led here to the deposition of ferric oxide as rusty streaks rather than as gravelly concretions. The soil cracks in dry weather and is often difficult to work, but it is regarded in the district as a desirable type. The clay in the deep subsoil is sometimes relatively light, especially where the type occurs on the higher levels. This is due to the fact that this soil is formed on natural lines of drainage, down which sand has been washed as well as the finer fractions. Some of the tongues of this type in the south-east of our area have important amounts of coarse sand, and approximate in texture to a sandy clay loam.

7. *Eumemmering Clay.*

The main continuous occurrence of this type is one of 1,010 acres in the Hallam Valley section, on land draining into the Eumemmering Creek. It also occurs in other basins where minor watercourses have spread over the land in such situations that the movement of water has been slow enough to allow suspended clay to settle, while swampy conditions have persisted long enough each year to allow a fair accumulation of organic matter. The swamp tea-tree reaches its greatest development in this environment.

The following profile is typical:—

Horizon 1. (0–6 inches)—Black clay, somewhat friable, drying into small crumbs when properly worked.

Horizon 2. (6–16 inches)—Dark-grey plastic, heavy clay.

Horizon 3. (16–35 inches)—Grey plastic, heavy clay.

Horizon 4. (35 inches downwards)—Heavy clay, with light-grey and yellow mottling.

The depth of the friable surface layer may be as little as 3 inches. It is at the best a refractory soil which can be easily worked only over a narrow range of moisture contents. It is particularly troublesome during the frequent wet winters and springs.

Horizon 2. (10–27 inches)—Grey or dark-grey heavy clay.

Horizon 3. (27 inches downwards)—Decomposing basalt, light-brown and gritty.

Strictly speaking one should distinguish between the black soils on higher slopes and those on the gentler, lower slopes. It is quite plain that the latter crack more on drying than the former, and as might be expected they have a deeper subsoil, in which the clay is as plastic and heavy as any in the district. The type sample was chosen as it occurs in the only extensive patch of black soil on basalt, but is not thoroughly representative, because being low-lying it has received both quartz sand and finer material from surrounding non-basaltic land. All these basaltic soils appear to be resistant to erosion, are rich in organic matter and friable considering their clay content, and possess a stable crumb structure which confers on them a good permeability. Small rocks or "floaters" occur through the profile, and often make it impossible to sample below a few inches. Every intermediate colour occurs between the extremes of "red" and "black": only the soils with really bright colours are mapped here as "red", the rest being "black".

The reason for the existence of the two types is not known. Similar contrasts occur farther east in Gippsland, and it seems very likely that these soils are analogous to the basaltic soils around Burnie, in North-western Tasmania, which have been surveyed by Stephens (6). Differences in soil type are not associated with any difference in the parent rock or in topography, except that red soils are not found on flat land. It is said that the black soils hold the moisture better and give heavier crops, but the red are more easily worked.

The native flora was undoubtedly very dense, and has left its mark in the high organic matter of the soil. To-day an occasional tall "white gum" (*E. viminalis*) remains on the basaltic country, a tree that contrasts with the much smaller "peppermints" around it on the podzolized types.

A very interesting feature of the basaltic ridges is the suddenness with which the soil changes at the foot of the slope into the poor podzolic type: the effect of basaltic wash is evidently very slight.

Miscellaneous Types.

A few areas have been mapped as "miscellaneous sandy types." These are all podzolic and naturally poor.

(i) Along Cardinia Creek is a line of deep sand, which is presumably a former bed of the creek. The profile varies from place to place, but typically there is sand to a depth of 4 to 5 feet, overlying a yellowish sandy clay. The sand is generally

less coarse than Cranbourne sand; its colour ranges from grey at the surface to light-brown in the lower levels, which sometimes contain soft brown concretions. Several small pits have been worked for this sand.

(ii) A small patch of deep fine sand changing to clayey sand below 4 feet occurs north-east of Officer. Its geological origin is obscure.

(iii) Interbasaltic sands.—Sandy deposits occur on the edge of the lava flows to the north of Berwick. Three of these consist of coarse sand, and the soil developed on them is grey coarse sand turning to light-grey below the surface, and changing at 3 feet to reddish-brown coarse sand with small inclusions of clay. A fourth deposit, covering a larger area than any of the others, consists of finer material, though probably it also was deposited by streams flowing at the edge of the basalt. The soil developed on this is a grey fine sand with ironstone concretions at 18 inches, lying over mottled red and yellow clay at 22 inches.

(iv) An unclassified "very fine sandy type" has been mapped with a different symbol from the soils just described. This soil occurs north of Beaconsfield, and has a remarkably silty feel, due to the large proportion of very fine sand which it contains. The surface is a grey silty loam, and the colour becomes lighter with depth: this passes at 22 inches into a yellowish-grey silty clay, and at 33 inches into a light clay which is mottled with red, yellow, and grey. This soil appears to be developed from foot-hill wash from the Silurian hills, which seem to have provided at this point an abnormal concentration of very fine sand and silt.

Significance of Soil Type.

The foregoing descriptions, and the more detailed analyses in a later section of the paper, show how greatly the soils of this district differ from one another. If the production of cash crops were common here, no doubt these differences would be reflected in the agricultural reputations of the various types. All the land is capable of being cropped, except where the slopes are too steep. However, grass is by far the most important crop throughout the district, except the Silurian hills where fruit is grown. It appears that, with the exception of the non-agricultural Silurian hills, there is little to choose between the various soil types as regards the productivity of well-managed pastures. Good pastures, including perennial rye grass, can certainly be established on all these types. However, the general development of good pastures in this district is so recent that there is no guarantee that the perennial pastures on the soils of low inherent ferility will prove as permanent as those on the better soils.

It is not possible to compare the various soil types with one another on the score of prices paid when land changes hands, but the soils on the basalt would probably command a higher price than the others.

Saline Patches.

Patches of land affected by a high concentration of salt are a conspicuous feature of the country, especially within 2 or 3 miles from Narre Warren. These patches occur at the foot of gentle slopes, and may spread out for 150 yards or more over the flats. The only plant that grows on most of them is a stunted form of a species of Plantago, and as shown in plate XI this alternates with bare ground. The immediately surrounding land carries less tolerant plants (see p. 237), and a few yards further away there may be normal pasture.

These concentrations of salt are evidently associated with certain properties of climate, topography, and soil. It is at first sight surprising to find accumulations of salt under an annual rainfall of 30 inches, with low evaporation during the winter. However, most of the rain comes as relatively light showers, and falls of over 1 inch in 24 hours make only a minor contribution to the yearly total; on this account, salt is not washed out so thoroughly as in districts where each fall of rain is heavy. The salt falls with the rain, being blown in from the sea in the form of evaporated spray, and its occurrence is not connected with the weathering of rocks. This matter has been fully discussed by Prescott (7) for Australia in general, and by Teakle (8) for the south-west of Western Australia. It may be estimated from unpublished data kindly supplied by Mr. V. G. Anderson that the annual fall of sodium chloride on the land near Berwick is 80 pounds per acre. The local concentration of this salt to give 10 tons per acre in the surface foot depends on soil and topography.

The soil of the ridges above the salt patches is one of the podzolic types, Hallam loam or Toomuc sandy loam, with a sharp boundary between the permeable surface and the subsoil, which is only slowly permeable. The rain after saturating the surface layers flows down the hill on the top of the clay, becoming more saline on its way as pure water is evaporated or transpired by plants. The water when it is checked at the foot of a slope may thus contain the salt that has fallen over many times the area of the salt patch.

History.

These salt patches are characteristically much more acidic than the surrounding land. This fact suggests that the high concentrations of salt are recent, since land that has long been influenced

by salt is usually neutral or alkaline. The older settlers also believe that the salt has appeared or has spread since the land was cleared, as has undoubtedly been the case elsewhere in Australia. However, it is said that there were at least a few salt patches when the land was first settled.

Treatment.

These patches make up so small a proportion of the average holding that even the most progressive farmers have not taken measures against them. The barrenness is certainly due to salt and not to acidity; liming does not improve matters. Crops which tolerate high concentrations of salt have not been tried.

V. Land Utilization: (A) General Considerations.

HISTORICAL INTRODUCTION.

When Victoria was first occupied by white men the whole of this district was covered by forests of various species of Eucalyptus, or by dense scrub on some of the flats. Settlers first arrived about 1835, but their numbers were small until the completion of the first survey by the Lands Office in 1852. In this survey the virgin bush was divided into blocks mostly of 640 acres, with a few of 320 acres; roads were marked out and small areas set aside for townships.

When the survey was completed the Lands Office offered some of the blocks for sale to members of the general public for £1 an acre. However, many of the eventual settlers had to pay considerably more than this, partly because some of the land was auctioned by the State but mainly as a result of the activity of speculators. Many blocks were bought by settlers who had not previously seen them, and this probably accounts for the fact that the first land to be alienated included low-class as well as high-class country. This applied, for instance, to a colony of Germans who settled around Harkaway, on country consisting largely of uninviting hills of granodiorite.

After partly clearing their blocks, the settlers started by growing crops, especially wheat and barley, which were the most profitable cash crops at the time. Wheat on the basaltic country north of Berwick originally yielded as much as 50 bushels per acre. A flour mill was also built at Berwick about this time.

During the sixties the price of wheat and barley fell, and rusts began to infect the wheat, which then consisted of non-resistant varieties such as White Tuscan and Purple Straw. There was accordingly a rapid change from cropping to dairying and mixed farming, for which also the freshly cleared land was used. Since then dairying has been the most important industry in the district.

The population of the district increased rapidly during the late fifties and early sixties, and a township sprang up at Berwick, where a post office, churches, and public halls were built about this time. The first schools were privately owned but a State school was opened in 1859. The district of Berwick was created a shire in 1868, and its progress since then is summarized in Table III.

TABLE III.—SHIRE OF BERWICK, 1880-1937.

Year.	Area in Square Miles	Population.	Number of Dwellings.
1880	312	3,200	..
1890	300	4,700	..
1900	387	6,500	..
1910	387	6,430	1,400
1920	384	7,900	1,600
1930	384	9,400	2,355
1937	384	9,700	2,550

This early settlement extended as far east as Cardinia Creek. To the south of the Prince's Highway and east of Cardinia Creek, settlement first took place in the seventies and eighties. Originally this land was used mostly for grazing sheep and beef cattle but dairying now plays a more prominent part. In the stony and hilly country east of Cardinia Creek and north of the Highway, settlement started considerably later; in fact, apart from the few orchards, much of this country though alienated is still not even cleared.

The surveyed district is close to Melbourne, and the lightly timbered flat to undulating country (especially in the south) was cleared at comparatively low cost. The district was favourably situated therefore for the supply, first of dairy butter and eggs, and later of wholemilk also, to Melbourne. Before the introduction of the cream separator about 1890 the butter was manufactured on the farms. The early German settlers around Harkaway walked along bush tracks to Melbourne with the home-made butter and eggs and sold them in the market. As better roads were made, carts and drays were used for transport, and eventually the railway. With the development of butter factories and of refrigeration on ships, the export of butter rapidly became an important industry which gave a good return to the dairy farmer supplying cream for manufacture into butter. In spite of this the dairy farmer in this district has long considered that supplying wholemilk to Melbourne is more profitable than producing cream for butter.

The development of the sheep and beef cattle industries in this district has been less striking than that of dairying. Close proximity to the metropolis is not so valuable to these industries as it is to dairying. However, there have always been a number of farmers in this district who derive part or all of the farm income from sheep, grown in former years for their wool but in recent years mainly for the sale of fat lambs.

More recent developments have been the planting of scattered apple orchards in the hills, mostly between 1915 and 1922, and various attempts at closer settlement, which are dealt with in a later section.

The price at which land changes hands naturally varies with individual cases, but farmers in the district have paid about £13 an acre during 1937 and 1938 for unimproved property under native grasses.

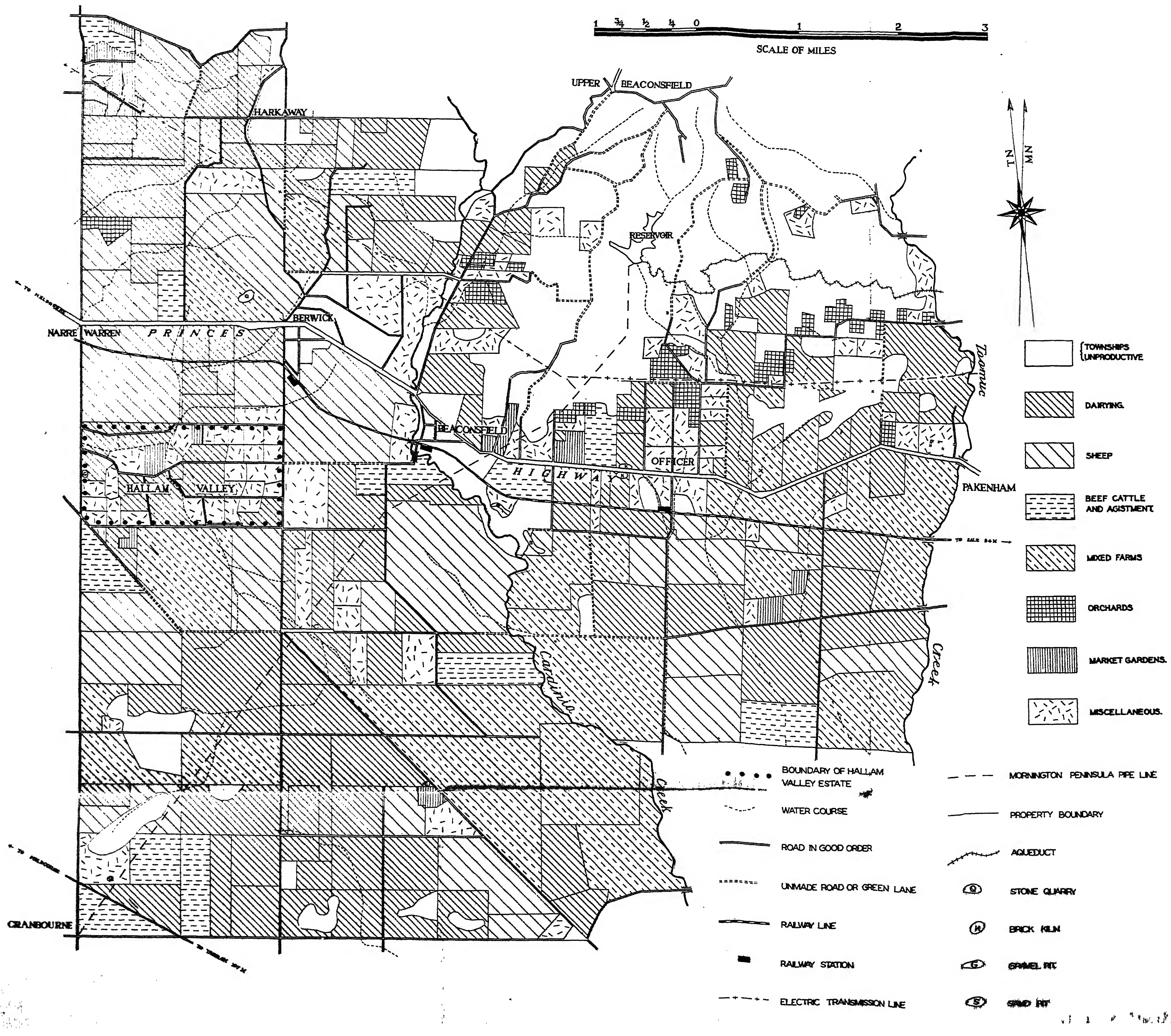
DEFINITION AND DISTRIBUTION OF FARM TYPES.

For the purposes of this survey 192 farmers were considered in detail. (The word "farmer" is used in a general sense in this paper, and includes the term "grazier.") This figure includes every one whose holding is not less than 20 acres. Information was not complete for all of these men; on this account, some of the group totals in the following Tables (as in Table VI.) fall short of the totals given in Table IV. The various types of farming, as discussed here, and as summarized in Table IV., are defined as follows:—A *dairy farmer* is one who milks a herd averaging more than eight cows, and who derives more than 80 per cent. of his farm income from dairying. Similarly, *sheep*, and *beef cattle and agistment farmers* are those deriving more than 80 per cent. of their farm income from these respective occupations. A *mixed farmer* is one who derives more than 20 per cent. of his farm income from each of at least two types of farming; usually sheep and dairying. *Orchardists* are those who derive at least 80 per cent. of their farm income from the sale of fruit. The *miscellaneous* group includes all other persons whose holdings exceed 20 acres, but who could not be classified according to the above scheme. This class is composed mainly of market-gardeners and flower-growers, and persons who work as labourers in addition to owning a small property.

TABLE IV.—DISTRIBUTION OF FARMERS ON BASIS OF OCCUPATION AND SIZE OF HOLDING.

Size of Holding (Acres).	Number of Farmers of Given Occupation.						
	Dairy.	Sheep.	Mixed.	Beef Cattle or Agistment.	Orchardists.	Miscellaneous.	Total.
20–99	38	4	1	1	22	21	87
100–199	33	3	7	4	2	6	55
200–299	8	6	5	4	..	1	24
300–399	4	4	3	..	..	..	11
400–599	2	1	6	..	..	..	9
>600	1	4	1	..	..	..	6
Total farmers ..	86	22	23	9	24	28	192
Total acres ..	12,040	6,850	7,420	1,580	1,140	1,980	31,010
Percentage of Total Area	39	22	24	5	4	6	100
Average size of farm in acres	140	311	321	176	48	71	162

FIG 7. MAP OF BERWICK AREA SHOWING LAND USE.



The distribution of the various types of farm is shown in fig. 7. The land mapped as *unproductive* is covered with "Peppermint" timber (*Eucalyptus australiana*) or is useless because of dense bracken or rushes. It will be seen that the farm types are scattered more or less at random over the area. Comparison with the soil map (fig. 6) indicates that apart from the orchards, which are confined to the Silurian foothills, soil type is not correlated with the type or size of farm. This is partly because cash crops like potatoes, which might force dairying and grazing off the better soils, are not grown here, and partly because even such inherently poor types as Toomuc sandy loam carry good pasture if well managed. Nor does there appear to be any relationship between the distribution of particular farm types and main roads, as might be presumed in the case of dairy farmers supplying whole milk to Melbourne. This is not really surprising since there are fine highways and a close network of fairly good side roads, and the dairy farmers are willing to transport milk to the highways if necessary.

The area within the boundaries of the map (fig. 7) is 40,170 acres, of which 31,010 acres are occupied by men who are actively engaged on the land and 2,550 acres are taken up by roads, townships, &c. Most of the remaining unproductive land lies in the rugged hills in the north-east of the area, where 5,200 acres are under native timber.

Systems of Tenure and Length of Tenure.

The systems of tenure under which the properties are conducted are shown in Table V. In this classification "owned" properties are not necessarily freehold; many of them are being bought under long-term "hire purchase" agreements. Rentals for leased properties vary from about 15s. to 30s. per acre per annum, depending on the type of country and the extent to which it has been improved. A few farmers in addition to

Table V.—Distribution of Farmers on Basis of Systems of Tenure.

System of Tenure.	Number of Farmers of Given Occupation.						
	Dairy.	Sheep.	Mixed.	Beef Cattle and Agistment.	Orchardists.	Miscellaneous.	Total.
Ownership	61	19	22	8	24	24	158
Leasehold	21	3	..	1	..	4	29
Sharefarmers ..	4	..	1	..	..	..	5
Total farmers ..	86	22	23	9	24	28	192
Owned farms as percentage of total ..	71%	86%	96%	89%	100%	86%	82%

Note.—"Owned" farms include those which are being bought under long-term hire-purchase agreements.

owning their property also lease part, or all, of an adjoining property, for grazing dry dairy cows, sheep, or beef cattle. Of the 192 properties considered, 158, or 82 per cent., are owned by the present occupiers. It is noticeable that all orchards are owned by the occupiers, whereas only 70 per cent. of dairy farms are so owned.

Table VI shows the length of time each property has been held by the present farmer or by his family. These figures indicate the extent to which land has been changing hands over the

TABLE VI.—DISTRIBUTION OF FARMERS ON BASIS OF LENGTH OF TENURE.

Number of Years on this Property.	Number of Farmers of Given Occupation.						
	Dairy.	Sheep.	Mixed.	Beef Cattle and Agistment.	Orchardists.	Miscellaneous.	Total.
0–2	22	9	..	..	..	7	38
3–4	19	1	2	..	2	3	27
5–9	12	6	3	3	4	3	31
10–14	7	1	3	1	3	3	18
15–19	9	1	4	1	3	..	18
>20	15	3	10	3	10	4	45
Total	84	21	22	8	22	20	177

NOTE.—For a property worked on the share basis, the figure refers to the owner and not to the share-farmer.

past few years. Only about half of the dairymen, sheep farmers, and miscellaneous group have been here longer than five years, and about one-third have been longer than ten years. Orchardists and mixed farmers are obviously the most stable, 45 per cent. having been here longer than twenty years. This movement of farmers is probably associated with inflated land values and the immobility of orchardists is possibly due to general depression in the industry. Fifteen per cent. of the properties are held as leasehold. Several of the owners of these properties are descendants of original selectors, and are living in retirement in Melbourne. It is obvious that leasehold is not a stable arrangement—for example, among the dairy farmers, only 1 in 20 of lessees (5 per cent.) has been here as long as ten years, compared with 45 per cent. for owners. The chief drawback of the leasehold system is lack of security of tenure, in consequence of which there is little incentive for the tenant to improve the pastures, buildings, fences, and water supply; in fact, much more top-dressing is done on "owned" than on "leased" properties.

The number of share farmers (5) is too small to allow any conclusions to be drawn.

SIZE OF HOLDINGS.

As shown in Table IV, the size of holding varies with occupation, from an average of 48 acres for orchardists to an average of 321 acres for sheep farmers. The large proportion of dairy farms in the smaller size-groups is noticeable; 82 per cent. of dairy farmers have less than 200 acres, compared with 37 per cent. of all other graziers (sheep, cattle, and mixed farmers). These figures must be qualified by the following facts:—(*a*) Sixteen farmers have land outside the area in addition to that within the area; and (*b*), four farmers own more than one property within the area, but we have counted each farm as a unit. About 10 per cent. of the land included in this table is unproductive, being covered with bracken, scrub, or timber, which is only slowly being cleared.

PASTURES.

The pastures may be divided into three classes:—(*a*) Unimproved native pastures which took possession after the timber was cleared, and in which kangaroo grass and wallaby grass are dominant; (*b*) improved but low-grade pastures, in which subterranean clover and perennial rye grass occur together with high percentages of inferior grasses and flatweeds; and (*c*) highly improved pastures, comprising perennial rye grass, subterranean clover, white clover, and cocksfoot. The areas of these classes were estimated by inspection on the various properties, and are summarized in Table VII. The relative importance of the last-named class (at present 23 per cent. of the total) is rapidly growing. It is rather higher among those grazing sheep and beef cattle than among the dairymen. The difference between the figures for total grassland and total area includes cropland (about 1,500 acres) as well as unproductive land.

TABLE VII.—CLASSIFICATION OF PASTURES.

—	Acreages Held by Owners of Given Occupation.					
	Dairy.	Sheep.	Mixed.	Beef Cattle.	Miscellaneous.	Total.
Unimproved native	3,800	2,130	2,100	520	990	9,540
Improved but low grade ..	4,110	2,670	3,070	420	270	10,540
Highly improved	2,080	1,780	1,590	560	40	6,050
Total pasture	9,990	6,580	6,760	1,500	1,300	26,130
Pasture top-dressed annually ..	6,230	5,000	5,140	1,100	220	17,690
Total area of properties ..	12,040	6,850	7,420	1,580	1,980	29,870
Number of farmers	86	22	23	9	27	167

Topdressing and Improvements.—An area of 17,690 acres, or 70 per cent. of the area under pasture, is now top-dressed each year at an average rate of 140 lb. per acre. If the 86 dairymen

are grouped with fourteen mixed farmers with whom dairying is an important activity, to give a group of 100 farms carrying dairy cows, the properties on which less than 50 per cent. of the farm is top-dressed carry one stock unit per 3.4 acres, compared with an average of one stock unit per 2.0 acres for properties on which more than 50 per cent. is top-dressed. Most farmers top-dress their pastures in the autumn, but some of those who use large amounts of superphosphate apply part in autumn and part in spring.

Thirty-five per cent. of the pastures are harrowed annually, generally before topdressing in the autumn. On many farms it was obvious that more harrowing was necessary for the purpose of spreading cow manure.

There are two alternative methods of improving the native pastures. The pasture may be ploughed up and one or two crops, usually oats, rape, or maize may be grown, and in the following autumn a mixture of grasses and clovers sown down—mainly perennial rye grass and subterranean clover. This method is the more expensive but it leads to a first-class pasture quicker than the alternative method, which is to give the rough native pasture a vigorous harrowing and then to sow a few pounds of a mixture of subterranean clover and perennial rye grass, and to repeat this process annually for two or three years. In this way by annual topdressings of one to one and a half cwt. of superphosphate per acre the pasture is gradually improved, and after five or six years the fertility is raised to such an extent that perennial rye grass and white clover persist. This method is less expensive and in the long run it produces as good a pasture as the other, the native grasses being unable to withstand the competition of plants which flourish under the conditions of higher fertility.

Pasture Species.—Subterranean clover and perennial rye grass are the two outstanding plants in the better pastures in this district. Other useful pasture plants, however, have their place, and white clover is the most important of these. Cocksfoot is important on a few properties, particularly on the hills. Strawberry clover does well on the heavier soils along depressions in the flatter country to the south. A few farmers have successfully combined subterranean clover with paspalum (*P. dilatatum*) which makes its growth during the summer after the subterranean clover has died. Other introduced species such as Yorkshire fog, crested dogstail, and sweet vernal thrive in this district, but their value is doubtful. It has been suggested in neighbouring districts that *Phalaris tuberosa* should be introduced on the clay flats, since it could be particularly effective in protecting the soil from puddling by cattle during wet winters. This grass does not appear to be used here as yet.

Chemical Fertility.—1. Phosphorus and nitrogen.—The inherent fertility of the lighter soils is low, and that of the heavier soils on the basalt and on the flats was seriously depleted in earlier years. For 60 years the soil was exploited and no artificial fertilizers were used on the grazing land. Topdressing with superphosphate started about 1920 but was not carried on extensively until 1930, and its use is still increasing rapidly—in fact, over the past three years the total area topdressed has increased by 30 per cent.

The general experiences on the coastal soils in Southern Australia which have been impoverished by centuries of heavy rainfall, is that the fertility must be built up by annual applications of superphosphate combined with subterranean clover, which adds nitrogen to the soil in a readily available form. The Victorian Pasture Improvement League (hereafter referred to as V.P.I.L.) has set up a series of experimental plots at Pakenham, just outside our area, on land very similar to the Hallam loam within the area; the observations made on these plots confirm the general experience of the district, that superphosphate results in a greatly increased growth and is the fundamental fertilizer on this country.

The status of phosphorus and nitrogen in the soil is thus brought to a satisfactory level by the combination of superphosphate and clover. Two other elements, potassium and calcium, are also of interest as possible limiting factors in production.

2. Potassium. The experiments of the V.P.I.L. in the Western District of Victoria have shown that on certain light podzolic soils the growth of pasture is much increased by potash salts. Many podzolic sandy loams in our area are very low in available potassium, and it would not be surprising to find a response to potash on those properties that have been heavily cropped in the past. As yet, however, there is no positive information on this point.

3. Calcium. The whole of the country to the south of the highway, except for the few basaltic ridges, was formerly notorious for "cripples" in stock. This disease appears to be a malformation of the bones due to a lack of calcium. The trouble has disappeared from the district since the introduction of superphosphate, which thus appears to have acted as a source both of calcium and of phosphorus.

Great interest has been aroused by the possibilities of lime. The usefulness of lime on these pastures is still a controversial matter, but apart from some highly acidic patches lime does not increase the growth of grass, and, of course, if lime is applied it can only be considered as supplementary to superphosphate and not a substitute. Though there is no evidence that lime increases the yield of pastures, farmers of sound observation

state that the stock prefer limed to unlimed pastures and are generally healthier on limed land. It seems likely that, if this is true, it is due to the provision of the necessary element calcium rather than to the neutralizing of acidity. The applications of lime have been light, of the order of two to three cwt. per acre.

Near Cranbourne in the sandhill country is a patch of 10 acres of land so intensely acidic (pH 3.1 to 3.5) that it will not even support subterranean clover, which is the most tolerant to acidity of all good pasture plants. Pot tests carried out at the School of Agriculture on samples of this sandy soil showed that about one ton per acre of lime was needed before subterranean clover and rye grass could persist. Such extremely acidic soil, however, is exceptional, and is not likely to be found in more than a few small patches.

Seasonal Growth.—Pastures produce a marked maximum of growth in the spring in this district, as elsewhere in southern Australia. The yields obtained on the experimental plots of the V.P.I.L. at Caldermeade are of interest in this respect. (Caldermeade is about 12 miles south-south-east of Pakenham, and is the only station of the V.P.I.L. making quantitative measurements which is near our area.) The pastures here are cut at convenient intervals and weighed; and the yield between mid-August and mid-November regularly amounts to two-thirds of the total for the year. Further, the yield in early summer (to the end of December) accounts for more than half of the remainder. The surveyed area probably shows an even sharper maximum in spring than does Caldermeade, where conditions are more favourable for growth into the summer. Dairymen supplying whole-milk to Melbourne have to meet the milk contracts all the year round, and hence it is desirable to overcome the effects of these major fluctuations if possible. The obvious way to do this is to conserve surplus pasture growth in late spring for use in the winter months when pastures are almost dormant. Conservation of meadow hay therefore constitutes a very important phase of the operations on the average dairy-farm. Sheep and cattle graziers usually stock more heavily during the spring flush, rather than conserve surplus growth as meadow hay. The various forms of supplementary fodder used on the farm may now be considered in turn.

FODDER CROPS.

Meadow Hay and Oaten Hay.—Fifty-eight dairy farmers grow oats, covering 660 acres and yielding about 1,200 tons. The varieties usually grown are Algerian for hay and Mulga for green feed. Except for these dairymen, oats are hardly grown at all, and the dairymen themselves have been steadily substituting meadow hay for oaten hay over the past few years.

Table VIII expresses the total hay (oaten and grass) conserved on properties in terms of cwt. per stock unit. The mean figure on the dairy farms is 16 cwt. per stock unit; on these

TABLE VIII.—DISTRIBUTION OF FARMERS ON BASIS OF CWTS. OF HAY CONSERVED PER STOCK UNIT.

Cwts. per Stock Unit.	Number of Farmers of Given Occupation.					
	Dairy.	Sheep.	Mixed.	Beef Cattle and Agistment.	Miscellaneous.	Total.
0	12	11	7	7	23	60
1–5	11	5	5	1	1	23
6–10	17	3	5	1	1	27
11–15	27	2	3	..	..	32
16–20	11	..	1	..	..	12
21–30	4	..	1	..	..	5
>30	4	..	..	..	2	6
Total	86	21	22	9	27	165

farms milking cows are given practically all the hay so that the figures underestimate the amount of hay conserved per milking cow. Only cautious conclusions can be drawn from the analysis of data collected because the figures are very approximate. This is due to the fact that the acreage of meadow hay cut and the yield per acre vary enormously from farm to farm and on any one farm from year to year. It appears that the average yield of meadow hay is about 25 cwt. per acre in the normal season. Table VIII shows that 36 per cent. of the total farmers conserve no hay and another 36 per cent. conserve each year between 1 and 15 cwt. per stock unit. This table shows how conservation of hay is almost confined to dairymen and mixed farmers, and even on the mixed farms the hay is conserved mainly for feeding dairy cattle.

It appears that even on dairy farms the amount of hay conserved is usually only sufficient to meet the normal winter requirements and there is very little reserve to cope with abnormally dry conditions such as those experienced during 1938. On all other types of farm the farm income could be increased considerably by conserving at least some of the surplus growth of the pastures in spring for the supplementary feeding of stock during the periods of limited pasture growth.

Green Crops.—The main crops under this heading are maize and millet grown for dairy cows, and rape, millet and mustard for sheep and fattening lambs. In favourable seasons oat crops are sown early in the autumn and give some useful winter feed to milking cows, as well as providing hay later in the year.

The acreage of maize and millet has decreased considerably over the past few years. This decrease may be correlated with pasture improvement. After ploughing up rough native pasture farmers would grow maize, millet, oats or rape for two or three years before sowing down to permanent pasture. Most of the productive area has now been treated in this way and farmers do not like ploughing up good pasture for the purpose of growing green crops or oaten hay.

Maize and millet are confined to 67 of the 100 farms on which dairying is a major activity. The respective areas under these crops are 430 acres and 300 acres; the total area works out at about 1 acre per three milking cows. By far the greater amount of these crops is chaffed with meadow hay and fed in the bails though on some farms the maize is cut and strewn in the pasture paddocks and the millet fed off. In addition to maize and millet, small areas of other crops such as mangolds, sudan grass and oats for green feed are occasionally grown.

About 25 per cent. of the sheep men grow some rape (usually 10 to 20 acres each) for fattening lambs and "topping off" store sheep, but this is the whole sum of the green crops grown by graziers.

Ensilage.—Only 5 per cent. of the farmers make ensilage of any description. Crops used for this purpose include maize and surplus pasture growth of all types. The silage is usually made in stacks, rather than in silos or pits.

Fodder Bought.—A great deal of fodder is bought for the supplementary feeding of milking cows during the periods when pastures are making little growth. Most dairymen rely to some extent on hay and green crops grown on the property and buy additional fodder according to the season. The quantities of such purchases are very variable. The weather was abnormally dry in 1938, and pastures made very poor growth. Hence farmers bought very large amounts of feed (mostly brewer's grains, bran, pollard, and chaff) in an attempt to maintain the milk supply of the herd and fulfil the contracts.

Amount of Stocking and Intensity of Stocking.

For the consideration of these two phases a stock unit was taken as one milking cow and factors were then adopted to convert other types of stock into stock units. The factors used are shown attached to Table IX, which indicates the number of stock units per farm. This number is, of course, considerably larger on the sheep and mixed farms than on dairy farms since the former are much bigger farms. However, dairying is represented by a greater total number of stock units than any other occupation in this district.

TABLE IX.—DISTRIBUTION OF FARMERS, EXCLUDING ORCHARDISTS AND MISCELLANEOUS GROUP, ON BASIS OF NUMBER OF STOCK UNITS PER FARM.

Number of Stock Units per Farm.	Number of Farmers of Given Occupation.				
	Dairy.	Sheep.	Mixed.	Beef Cattle and Agistment.	Total.
0–15	5	2	..	..	7
16–30	23	3	1	..	27
31–45	22	..	4	2	28
46–60	18	2	..	2	22
61–75	8	..	2	1	11
76–90	4	1	1	1	7
91–105	2	7	1	1	11
106–120	1	1	2	..	4
121–150	1	1	5	..	7
151–180	..	1	2	..	3
181–210	2	1	..	2	5
> 210	..	3	4	..	7
Total Farmers ..	86	22	22	9	139
Total Stock Units ..	4,020	2,630	2,930	810	10,390

The figures in the above table have been calculated using factors as follows:—One "stock unit" comprises 1 dairy cow, 1 dry cow, 1 heifer or steer over 9 months old, 1 horse, 2 calves under 9 months old, 10 sheep, or 15 lambs.

As may be seen from Table X, 60 per cent. of farmers carry stock at the rate of between 1.5–3 acres per stock unit. This table also shows that on the smaller properties (less than 100 acres) the intensity of stocking is greater than on the larger properties. The intensity of stocking is not markedly correlated with occupation, but it is highly correlated with the degree to which pastures have been improved and top-dressed. A particularly interesting fact is the absence of any connexion between carrying capacity and soil type on the more improved properties. Prominent farmers agree with our observations that with intelligent management the poorer podzolic types will carry as much stock as the richer basaltic types.

TABLE X.—DISTRIBUTION OF FARMERS, EXCLUDING ORCHARDISTS AND MISCELLANEOUS GROUP, ON BASIS OF ACRES OF PRODUCTIVE LAND PER STOCK UNIT AND SIZE OF HOLDING.

Acres of Productive Land per Stock Unit.	Number of Farmers Holding Acreages as Below.						
	20–99.	100–199.	200–299.	300–399.	400–599.	> 600.	Total.
< 1·5 ..	3	1	3	1	..	..	8
1·5–2·0 ..	14	1	3	..	1	..	19
2·0–2·5 ..	14	8	6	3	1	2	34
2·5–3·0 ..	9	9	5	2	2	1	28
3·0–3·5 ..	7	11	4	2	1	1	26
3·5–4·0 ..	1	6	1	1	1	1	11
4·0–5·0 ..	2	4	2	..	..	..	8
5·0–6·0 ..	2	2	..	..	..	..	4
Total	52	42	24	9	6	5	138

MISCELLANEOUS.

Subdivision.—The extent of subdivision ranges from an average of seven paddocks per property of less than 100 acres, to sixteen paddocks per property of more than 400 acres.

Water Supply.—The main source of water for stock is from dams. In addition many properties are served from water reticulated or fed direct from the two large creeks (Cardinia and Toomuc) running through the area. About 30 farmers have tapped the Mornington Peninsula Pipe Line; this, of course, ensures a permanent supply of water. In the flat and undulating country to the south many farmers have sunk bores and generally obtained an excellent supply of permanent water, at depths ranging from 30 to 80 feet.

Approximately a quarter of the farmers have an inadequate supply of water; that is, insufficient to cope with normal requirements during an average summer. Another quarter have a fairly good water supply from dams and creeks which is sufficient to cope with a normal summer but may fail during abnormally long periods of dry weather. About half of the farmers have a permanent supply of water; this includes farmers who have tapped the main pipe line and those who have a frontage on either Cardinia Creek or Toomuc Creek, and also about twenty men (mostly in the south) who have a more or less permanent supply of bore water.

Machinery.—The number, type and standard of implements on each property varies greatly. On practically every property apart from a few leasehold and "miscellaneous" farms, there are sufficient implements to carry out routine farm work such as ploughing, cultivating, sowing of crops and top-dressing. However, many farmers do not possess the implements necessary for making hay and do this work either by contract or with borrowed machinery. A development over the past three or four years has been the introduction of the sweep in haymaking. On most farms horses provide the power necessary for doing the farm work.

Windbreaks.—Bleak winds associated with antarctic storms occasionally blow from the westerly quarter during the colder months of the year. The chilling effect of these winds probably reduces the output of the dairy cows during the winter, and there is a risk of losing sheep after shearing in the spring through a sudden spell of cold wind. However, the desirability of plantations to serve as windbreaks for the stock in the paddocks has been appreciated only during the last few years. About 60 per cent. of the properties to-day carry plantations of fast-growing trees such as cypress.

CLOSER SETTLEMENT.

Since the early twenties the Closer Settlement Board has been active in buying land in various parts of Victoria, for the purpose of settling returned soldiers and others who could not otherwise afford to buy a property. Much of this land in Southern Victoria was divided into holdings of 100 acres or more, on which an efficient settler could dairy successfully. Other areas were cut up into smaller blocks (10 to 30 acres) designed for market gardening. These holdings were made available to settlers under long-term agreements which were more generous than the private purchaser would receive.

There have been three such areas in the district under survey. One of these areas was situated $1\frac{1}{2}$ miles south-east of Officer but settlement did not take place and the small blocks reverted to larger holdings. A second, at Narre Warren North, has been fairly successful, and several flower-growers and market-gardeners are established there to-day. The third and largest undertaking was in Hallam Valley (see map, fig. 7, for boundaries within our surveyed area). This was one of the unsuccessful attempts at closer settlement in Victoria, and is considered here in more detail.

Hallam Valley Settlement.—The State Rivers and Water Supply Commission was responsible for the subdivision in Hallam Valley in 1927. The subdivided area runs just south of, and almost parallel to, the main Gippsland railway line, from Hallam station to Berwick station. The area here surveyed includes only sections 3A and 4 of this scheme. These are identical with allotments 25 and 26 in the Parish of Berwick, which were sold to the State Rivers and Water Supply Commission in 1924 for £15 to £18 per acre. This price reflected the optimism of the period, since the flat country was covered with dense tea-tree and was periodically waterlogged, while the rising land, which was naturally poor, had been cleared of timber but not otherwise improved.

The Commission cleared the swamp area of scrub and subdivided the land. The part in which we are here interested, comprising 1,153 acres, was cut up into 67 blocks, on most of which houses were built. The area of these blocks ranged from 12 to 26 acres, with an average of 17 acres; this small size was suitable for the intended occupation, namely, growing vegetables.

Two large drains were constructed through the settlement to carry off flood waters and natural drainage. The effectiveness of the drains was increased by the construction of levee banks. In addition, on the flatter and wetter parts of the settlement sub-surface drainage was assisted by 3-in. pipe drains. A network of roads was constructed and some were equipped with concrete drains. As the settlement was principally designed for

market gardening, a system of water-supply pipes was installed on many blocks. Water was obtained by tapping the main pipe-line of the Mornington Peninsula water-supply scheme. The total capital cost of all these improvements was added to the initial cost of the land, bringing the cost to the settler to about £60 per acre in some cases.

The history of the settlement was disastrous. Within three years settlers were leaving, and by 1936 none of the original settlers remained. On the original 67 blocks there are now 32 houses only. Most of the holdings reverted to the Closer Settlement Board, and many of them have been resold; six farmers to-day own 35 former blocks between them. One is a market gardener, the others are small dairy farmers and apparently are quite successful. This grouping of blocks into dairy farms of 60 to 90 acres would appear to be the ultimate fate of this settlement. Several of the small blocks are vacant at present, and a few are held by men running poultry in small numbers. The rest of the houses are occupied by invalid soldier pensioners who may run a few cattle on agistment but otherwise do not use the land.

In reviewing the causes of this failure, one must recognize that market gardening requires an exceptional amount of knowledge and skill. The special features of districts around Melbourne in this respect have not yet been described in a publication, but it is certain that there is a great deal of special information which is jealously guarded by many of the producers. Without such special knowledge success would be achieved only by the painful process of experimentation based on trial and error, and it appears that the settlers had little previous experience. It would have been difficult for them to pay for water and to meet the high interest charges during such a period of trial. Further, while low prices were mainly responsible for the failure, there were local problems, associated with the two soil types which are found here—namely, Hallam loam (p. 189) on the rises and the strongly contrasted Eumemmering clay (p. 191) on the reclaimed swamp.

Hallam loam is a grey podzolic soil of low fertility, being poor in several essential elements. Moreover, it has a silty texture and tends to set to a hard surface after being saturated with water. It is, of course, common for market gardeners to work with poor and light soils and to add large amounts of fertilizer and manure, and in fact there are many successful vegetable growers nearer Melbourne whose soils are similar to Hallam loam. However, the land at Hallam Valley has no advantage to offset its greater distance from the city. The value of the land is also diminished by concentrations of salt on many

of the lower slopes. The patches of salty land are larger and more numerous than elsewhere in the district, one patch covering about 10 acres.

The chemical fertility of Eumemmering clay is not low by Victorian standards. Its physical properties, however, lead to difficulties in working the soil. As with other clayey soils, expert judgment is needed in choosing the right degree of moisture for a cultivation. In a wet winter the soil remains permanently wet and gets badly puddled. The subsoil consists of such impermeable clay that the drains at a depth of 3 feet are not at all efficient. Since the soil retains large amounts of water, the loss of heat involved in the evaporation of this water in spring and summer keeps the temperature of the soil relatively low. On this account early crops are not possible, and vegetables come on the market in competition with all other mid-season or late districts, when low prices often prevail. In such conditions, only the most favoured localities can remain in production, and this area does not seem to have any competitive advantage over districts at a similar distance from the city. One naturally compares this area with the reclaimed swamp land round Kooweerup, which is a major source of mid-season vegetables for Melbourne and is a few miles further away. The better soil types of Kooweerup, however, are much superior to the Eumemmering clay.

V. Land Utilization: (B) Individual Occupations.

Dairy Farmers.

There are 86 farmers who derive more than 80 per cent. of their farm income from dairying. In addition, fourteen of the mixed farmers derive a considerable part of their farm income from dairying, and hence 100 farmers, or more than half the total in the district, are to some extent dairymen. These 100 "dairy farmers" are considered together in this section except in Table XI., which refers to the activities of the 86 full-time dairy farmers.

Table XI.—Distribution of Dairy Farmers on the Basis of Number of Milking Cows and their Percentage of Total Stock Units.

Number of Milking Cows.	Percentage of Total Stock Units.							Number of Farmers
	0–39.	40–49.	50–59.	60–69.	70–79.	80–89.	90–100.	
0–9	..	..	..	3	2	..	..	5
10–14 ..	..	..	3	2	..	1	..	6
15–19 ..	..	..	3	6	6	2	..	17
20–24 ..	..	1	1	6	..	..	..	8
25–29 ..	..	..	4	5	3	2	..	14
30–34 ..	..	2	4	4	4	2	..	16
35–44 ..	..	1	1	2	2	1	..	7
45–54 ..	..	..	3	4	1	..	1	9
55–74 ..	..	..	1	..	..	..	..	1
75+	..	1	..	1	1	..	..	3
	0	5	20	33	19	8	1	86

Size of Herd.—It will be seen from Table XI. that the predominant size of herd is 15–35 cows, and that the milking cows make up between 50 and 80 per cent. of the total stock units. The totals for the 86 dairymen are 2,504 cows and 4,020 stock units. The average size of herd would be little affected by including the full 100 dairymen in this table.

Stock Diseases.—There is not much detailed information available about stock diseases but evidently disease is not a major factor. In the interests of public health the Milk Board keeps a strict supervision over the source of Melbourne's milk supply. It is, of course, known that contagious abortion, mastitis, and tuberculosis do occur, but farmers are naturally reticent in giving information.

Breeds, Herd Improvement and Yields.—There are only two pedigree herds (both Jersey) amongst those considered. Most of the cows are mixed dairy types with a very large proportion of Jersey blood. Thirty-four of the farmers use pedigree bulls of which 21 are Jerseys and 9 are Guernseys. The remainder use bulls of mixed ancestry, usually with Jersey predominating.

A peculiarity in this district is the extent to which farmers buy cows in the Dandenong Stock Market. Information supplied by farmers suggests that the average annual replacement is in the region of 20 to 25 per cent.. About 45 per cent. of farmers breed enough stock for replacement, but under the conditions of a milk contract it is essential to buy extra milkers during the winter and at any other time when production falls below the minimum set by the contract.

Ten of the farmers have their herds regularly tested for butterfat; of these seven are members of the Pakenham Herd Testing Association and the remainder test privately. Very little information regarding yields is available. However, estimates of the yields of fifteen herds (including the ten herds cited above) comprising about 500 cows show the average production to be approximately 270 lb. of butterfat per cow, per annum. These include some of the best farmers in the district, so that the average for the whole district is probably far below this figure. Thus it appears very likely that herds could be much improved by the incorporation of the progeny of tested parents bred on the property. It might be argued that this is a wholemilk district, for which butterfat tests would be of little value, but even so it is surprising that farmers should not even weigh the milk of the members of the herd.

Milking Machines.—Only ten of the farmers use milking machines. Eight of these use a 3-unit plant, but two farmers with large herds have 5-unit plants. On the other 90 farms the milking is done by hand, in most cases by the farmer and his family. One reason that has been given against the use

of machines is that some dairy retailers refuse to accept milk so obtained, since they believe that it is necessarily contaminated. Whatever truth there is in this assumption is probably due to lax methods of cleaning the plant. This does not seem, however, to be the main factor responsible for the prevalence of hand-milking. The reason appears rather to be that the initial cost of machines is high, and family labour is usually available; in fact, 85 per cent. of the total hand-milking is done by the farmer and his family, at an average of one milker to eleven milking cows. Wage ratings for dairy farm-labourers in this district are in general 25s. to 30s. per week plus keep, and it seems likely that this wage level would not be attractive to skilled men.

Pigs.—Little accurate information concerning pigs is available. Pig raising is confined to the 29 dairymen who produce cream. From the approximate figures collected it appears that these farmers annually breed and fatten one to two pigs per milking cow. This figure varies from year to year, and from one property to another, depending on such factors as the number of calves reared, the productivity of the herd, and the expenditure on extra feed, such as barley. The number of pigs fattened depends also on whether they are sold as baconers or porkers; the latter is the more usual. Some of the principles of pig management are not fully appreciated; many farmers feed only skim milk to the pigs, and do not attempt to balance the ration with cereals high in carbohydrates. It seems likely that this is one of the sidelines of the dairying industry which could be more profitably exploited.

Destination of Milk Products.—Thirty-five of the 100 farmers send all their milk to Melbourne dairies, and eleven send it to local butter and cheese factories. Twenty-five send their milk to Melbourne dairies, and sell some of their spring surplus to local butter and cheese factories. The remainder (29) keep pigs and sell cream to local or suburban butter factories. The local butter and cheese factories pay for wholemilk on a butterfat basis, paying slightly more per unit of butterfat for milk than for cream. This small margin, it is claimed, compensates for loss of profit from pigs.

There is no doubt that supplying wholemilk to Melbourne pays better than selling cream, or than supplying wholemilk to local factories. However, the former system has several drawbacks, the chief of which is the expense incurred through buying extra feed and also extra cows during the winter months to maintain the production above the minimum required by the contract. It is very desirable to do this, as the Melbourne retailer throughout the flush period in the spring and early summer commits himself to accept only as much milk as was supplied on the average throughout the winter. By bringing cows into

production all the year round, and by buying more cows during the winter, the wholemilk producers avoid the necessity of having to sell a large spring surplus to the butter factories. Second in importance probably are the regular and often inconvenient hours which have to be kept because the milk has to be ready when the milk wagon calls. Thirdly, such dairy farmers have to work all the year round, and cannot " dry off " most of the herd during the winter months. Fourthly, fodder taints, such as that attributed to subterranean clover, give difficulty during the spring. Such taints are much more serious in wholemilk than in cream supplied to a butter factory. These and other minor factors tend to make the costs of producing wholemilk for the Melbourne supply considerbly greater than the cost of producing cream for manufacture into butter, but the increased returns much more than compensate for this.

Conclusions.—To sum up, it appears that the production in dairying could be considerably increased. In fact, the very lack of numerical information concerning production confirms this statement, since it shows that the breed of the cows is not being deliberately improved, and this is probably the weakest feature of the industry. The farmers do not generally breed their own cows, and those who do breed do not usually select them; if they did so select, the total production would probably be lower for the time being, and the rental value of the land may be too high to allow for the long-range policy of improving the breed.

Mixed Farmers.

Information as to the activities of the mixed farmers is contained at various points in this paper. With two exceptions they combine dairying with sheep-raising; one combines dairying with orcharding, and one combines dairying with raising beef cattle.

Sheep Farmers.

General.—Information relating to the operations of sheep farmers may be obtained from the composite tables. Figures indicating the amount and intensity of stocking are not as reliable as the corresponding figures for dairy farmers because the number of stock on a sheep farm is continually changing. This is due to the fact that the farmer breeds lambs and buys " store " sheep which are sold when fat. Observations suggest that the fluctuations in numbers of sheep on the property are closely correlated with the growth curves of pasture as given in V.P.I.L. Reports. (See p. 204.) The difference between dairy and sheep farmers in this respect is that the dairymen conserve some of the surplus spring growth as meadow hay and feed it to the cattle in the winter. The sheep farmers, on the other hand, have many more stock on the property during the spring flush and sell these extra stock when pasture growth falls off.

In addition to the 22 full-time sheep farmers there are 22 "mixed" farmers interested in sheep, of whom eleven devote more than 50 per cent. of their property to sheep. Thus of 44 farmers grazing sheep 33 derive more than half of their farm income from this source. Some of these men concentrate solely on breeding and fattening lambs; others produce some fat lambs, and in addition buy and fatten store wethers and weaners. There are also some who run stud sheep. There are nine small studs of English breeds which provide sires not only for the farmer's own main flock but also for sale to other farmers in the district.

The wool clip is an important asset to all these men, but it does not constitute the main part of any farmer's income in this district, although farmers naturally pay considerable attention to the quality of the wool in their choice of breeding stock. The land has a high price, and this appears to determine its use for fattening sheep rather than growing wool. The wet and frequently bleak weather of the three winter months is also considered unfavourable to the fine-woolled breeds with their liability to footrot, though the winter here is probably less severe than in some of the wool-growing parts of the Western District of Victoria.

The Flock.—Considering the diversity of this occupation and the great fluctuations in the numbers and types of sheep on each property it is difficult to present in tabular form an accurate picture of the numbers of sheep. However, on the 44 farms considered there are approximately 22,000 breeding ewes which produce about 80 to 85 per cent. of fat lambs. In addition, about 5,000 store wethers are fattened annually. Comparison of the figures collected shows that on dairy farms the stocking is rather more intense than on sheep farms.

Approximately 80 per cent. of the sheep farmers have breeding ewes which are crossbred between the fine-woolled Merino and the meat-producing English types; the remainder have either Comeback, Merino, or English breeds of ewes. The crossbred produces a good class of wool and also stands the winter fairly well. Approximately 50 per cent. of the rams used for mating with these ewes are Southdowns; Border Leicesters are next in favour.

Wool Clip.—It is difficult to give definite information here because of the fluctuations in the number of sheep from year to year. The 1938 season was particularly unfavourable for collecting such information, because a number of sheep from Northern Victoria were being grazed in this district on agistment.

Diseases and Flock Management.—The incidence of disease is fairly low. In fact, the work associated with keeping the sheep healthy and in good order is carried out more efficiently than is the improvement of the pastures. Of the common diseases affecting sheep, footrot is easily the most important, especially on the flatter and badly drained properties. Other disorders such as liver fluke, lung worm, pulpy kidney, and blowflies cause a certain amount of trouble. The lambs are normally born from late June to August, and sold from late December to March or April. The time at which the sheep are shorn varies from early October to late November.

Beef Cattle and Agistment Farmers.

Of nine such farmers in the Berwick District, seven own their properties and run their own cattle, the other two take in agistment stock, which are mostly beef cattle. This number is too small for attempting statistical treatment, and so generalizations only can be made. However, some information on the operations of these graziers may be obtained from the various preceding Tables. The average size of holding is 176 acres; the standard of agriculture as shown by the amount of topdressing is comparatively high.

In addition to these men whose main occupation is running cattle, there are several mixed farmers who run some beef cattle, which eat the rough pasture which is not attractive to sheep. The possibility of developing the production of a small number of "baby beef" cattle on dairy farms has not been exploited, probably because the average dairy farm is just large enough to graze a herd which the owner and his family can manage efficiently.

Herefords are kept in the greatest numbers, and next in importance are Shorthorns. Most of the herds are very mixed in type, however, since they include many spayed dairy culls for fattening, also some of the beef men are interested in growing young dairy types up to the "springing stage" and catering for the large demand from local dairy farmers for milkers during periods of low production.

Most beef cattle farmers in the district agree that dairying, or even sheep farming, produces a larger cash return per acre; but, on the other hand, producing beef cattle is a much more congenial occupation.

Orchardists.

The 25 orchardists constitute only a small sample which is perhaps not representative of the many orchardists in the undulating or hilly country east of Melbourne. Most of the

orchards in the surveyed area were planted between 1915 and 1922, and the majority of the present holders are the original settlers. The settlers spent much capital and energy in clearing the timber before planting their orchards. The cost of clearing was undoubtedly high, although no exact figures are available; and this cost, plus the living expenses for the five or six years during which the young fruit trees were growing and giving no return, consumed the holders' reserves or involved them in debts which were to prove a burden in the years to come.

Topography and Soils.—Orcharding is the only occupation in this district which is associated with particular soil types. Twenty-two out of the 25 orchards are on the Silurian phase of Hallam loam (described on page 189) situated on gentle to moderate slopes, and the other three are on Harkaway sand (page 187), derived from granodiorite.

Cultural Practices.—The owners do the regular work of the orchards themselves and employ very little permanent labour. They do, however, employ a good deal of casual labour for five or six weeks during the height of the picking season. The routine operations of the orchards call for little comment.

Every orchardist has, in a normal season, sufficient water for spraying. Seven out of the 25 orchardists also conserve sufficient water in dams to irrigate some of the trees. Irrigation is confined to the variety Yates as a rule, in order to get the fruit on these up to commercial size. Yates trees receive six to eight waterings during the summer, depending on the season and the supply.

The usual application of fertilizer is five or six pounds per tree of a mixture consisting of superphosphate, sulphate of ammonia, and chloride of potash, in the proportions 2:2:1. Most orchardists apply half a ton of lime per acre every two or three years. In some of the orchards the trees show only mediocre growth due to insufficient applications of fertilizer, in most cases because of the owner's lack of capital. A curious problem with which a few orchardists have to contend is the presence of land crabs or "yabbies." The crabs in the heavier low-lying flats excavate large holes (up to 30 inches in diameter) 2 or 3 feet below the surface. In wet weather the holes fill up with water and the sub-surface drainage problem is accentuated. Pouring solutions of copper sulphate down the tunnels is said to be effective against the crabs.

Size of Orchard.—The size of the holdings and the orchards is summarized in Table XII, in which one "mixed farmer" is included with those who are purely orchardists. These 25 orchardists hold 1,300 acres of land of which 370 acres are planted to orchard, 700 acres are cleared and in pasture, and the remaining 230 acres are still uncleared bush.

TABLE XII.—DISTRIBUTION OF ORCHARDISTS ON BASIS OF TOTAL HOLDING AND OF AREA PLANTED.

Distribution on Basis of Size of Holding.		Distribution on Basis of Area of Planted Orchard.	
Size in Acres.	Number of Orchardists.	Size in Acres.	Number of Orchardists.
20–40	12	3–9	3
40–60	7	9–13	10
60–80	2	13–17	4
80–170	4	17–21	5
		21–45	3

Varieties.—The most common varieties originally planted were Jonathan, Yates, and Delicious. These varieties are still very popular; but over the past six to eight years many old stock such as Reinette, Gravenstein, and Yates, have been reworked to Granny Smith. Yates has declined in popularity, partly because its good keeping qualities have become less important since cool storage developed, and partly because of the additional work involved in thinning and irrigating.

The present acreages of the several varieties are as follows:—

Jonathan	118
Granny Smith	68
Yates	63
Delicious	26
Miscellaneous—Democrat, Gravenstein, &c.	31
Young trees not yet full bearing	60

There are also 14 acres under pears, cherries, peaches and lemons.

Yields.—It appears that in this district there are large variations in the average yields between one orchard and another, and also on any one orchard from season to season. Fairly accurate figures for yield were available for 20 of the 25 orchards, and the average of these was 1.5 bushels per tree, or 150 bushels per acre. As some of the orchards average 2 to 3 bushels per tree it would seems that production for the district could be increased considerably.

Soil Fertility.—The natural chemical fertility of these soils is low; further, they are liable to erode, and the presence of stones up to 3 inches in length makes for difficult working, and increases the wear and tear on implements. It is a tradition in Victoria that fruit trees should be planted on poor country. The chief merit of this appears to be that the fruit from such trees keeps better in cool storage, but this hardly compensates for low yields, although other districts with somewhat similar soils and more favourable slopes have achieved a fair success.

Drainage.—Three hundred and twenty acres, or 87 per cent. of the area planted to orchards is tile-drained. The upper soil is loamy and permeable to a depth ranging from 6 to 15 inches,

and the subsoil is a heavy clay; but many of the drains have been sunk too deeply into this clay, so that the improvement caused by drainage is not so general as one might have expected. In addition, some of the drains run in the direction of greatest slope and so lose most of their effectiveness.

Erosion.—It appears that on the stony Silurian soil, if the slope is greater than 5 degrees and the soil is cultivated there is a great tendency to erode. Since many of the orchard slopes are as steep as 10 degrees a great deal of surface soil is eroded and the fertility of the upper slopes is depleted; in fact, in some places the trees are now growing on the subsoil, all the surface soil having been washed away. It is obvious from the topography that much of this hill country should never have been devoted to a type of agriculture in which the soil is fallowed during the summer months. However, the capital has been expended and the difficulty now is how best to control erosion and increase fertility. It is said that the worst damage is done by thunderstorms in summer when the land is bare. The records for Melbourne show that a fall of at least half an inch of rain in an hour occurs on an average three times in four summers, and a fall of at least an inch in two hours occurs once in four summers. The corresponding figures for this orchard country are not known, but the frequency of heavy falls is certainly greater than in Melbourne.

Erosion can probably be minimized by cultivation along the contours instead of in the direction of the greatest slope as at present. However, some orchardists maintain that this hampers drainage, and the trees eventually die through "wet-feet." The accuracy of this latter statement has not been verified.

The possibility of planting trees along contours in order to facilitate contour ploughing, as has been advocated in other countries, has not been explored in this district.

Economic Position.—The orchardists of this district share in the general financial difficulties of the apple industry. Many of them have been particularly unfortunate, since after undertaking the heavy initial cost of clearing, draining, and planting, and providing for themselves during the five or six years while the young trees were still not producing, they were faced almost at once with low prices which did not allow them to recover their outlay. Further, while fertilizers and sprays involve a heavy annual expense, yields are generally not high, and many orchardists spend considerable labour and money in scooping back the soil that has been washed down the slopes. In these circum-

stances, and in view of the unlikelihood of any great rise in the price of apples, it appears that the only possible avenue of relief for many of these men is to supplement their income with sidelines. This possibility has not been exploited in the past; except for one man who is doing some poultry farming, another who has a tractor and is doing contract work for his neighbours, and two others who do some dairying, all the orchardists in this district depend almost solely on orcharding for a living. By keeping a few poultry and perhaps a few dairy cows they could increase their income substantially. It appears that if within the next few years the farm income is not increased by either higher yields or supplementary income from sidelines, then many of these orchardists must be absorbed in other industries.

Miscellaneous Farmers.

Of the 28 miscellaneous farmers only nine depend solely on their property for their income. Of these four are market gardeners, three are flower-growers, and two run poultry.

There remain nineteen holdings in this miscellaneous section, whose occupiers do not derive their main income from the property. Except for four owners who do not use their land at all, the small property is really a worker's home, and in addition provides a small income from the few dairy cows, and occasionally from stock on agistment. These men derive the rest of their income from other sources; viz., wages for work done for neighbouring farmers or for such bodies as the Country Roads Board, or alternatively from running a business in one of the local townships. As the means by which the miscellaneous farmers obtain their living are very diverse it is difficult to present in tabular form a picture of their activities. However, Table V shows that 86 per cent. of such properties are owned, and Table VI that most of the owners have been on their present properties for several years. While almost all the land held by such farmers is productive, the standard of farming is low. Pastures are poor, and there is little top-dressing or conserving fodder for the winter. This is not surprising where the owners have little capital and have other sources of income.

General Conclusions.

The area as a whole provides an example of the extent to which naturally poor country can be economically converted into good pasture land in a district of fairly generous rainfall. During the first half-century of settlement farmers increased their

production by clearing fresh land rather than by intensifying production on land already cleared. More recently, however, intensification has become the rule; improvement with superphosphate and introduced pasture plants has been particularly rapid since about 1933, and is still progressing. There seems to be no reason, other than shortage of capital, why all the flat or gently sloping land should not be brought up to the carrying capacity of the better dairymen—namely, the equivalent of one cow to 2 acres; it should be possible for dairymen working at this capacity to confine their purchases of additional fodder to a protein supplement for two winter months. The present rate of stocking is approximately one cow to 3 acres. Such an improvement is independent of the further need for raising the quality of the cows.

The amount of cropping has never been great, and has declined for several years past. Heavy crops of potatoes and onions were grown in the early days on the basaltic soils, but these crops are not grown there to-day though they would probably still give good yields. The only cash crops grown in the district are small amounts of vegetables, for which this district does not seem to hold any particular advantage.

The definitely hilly country presents a different problem. This land is not suitable for agriculture, and in some places its exploitation has led to financial loss. Most of this section is probably best left under its present cover of Eucalyptus.

VI. Chemical, Physical, and Mineralogical Analyses of Soil Types.

A few samples were chosen from each main type going to a depth of 3 to 5 feet. Routine laboratory analyses were done on the various horizons of each of these typical profiles.

Mechanical Analyses.

Complete mechanical analyses were carried out on selected profiles from each type of soil. The details are given in Tables XIII to XXI, in which the percentages are in terms of oven-dry soil. The mechanical fractions are defined by the "International" limits, viz., Coarse sand, 2.0 to 0.2 mm.; Fine sand, 0.2 to 0.02 mm.; Silt, 0.02 to 0.002 mm.; and Clay, less than 0.002 mm. These figures have been recalculated to a basis of sand + silt + clay = 100, and the results are expressed diagrammatically for

representative samples in Fig. 8. This diagram shows strikingly the sudden transition from the light surface to the heavy subsoil in the podzolic Harkaway, Hallam, and Toomuc types, and the

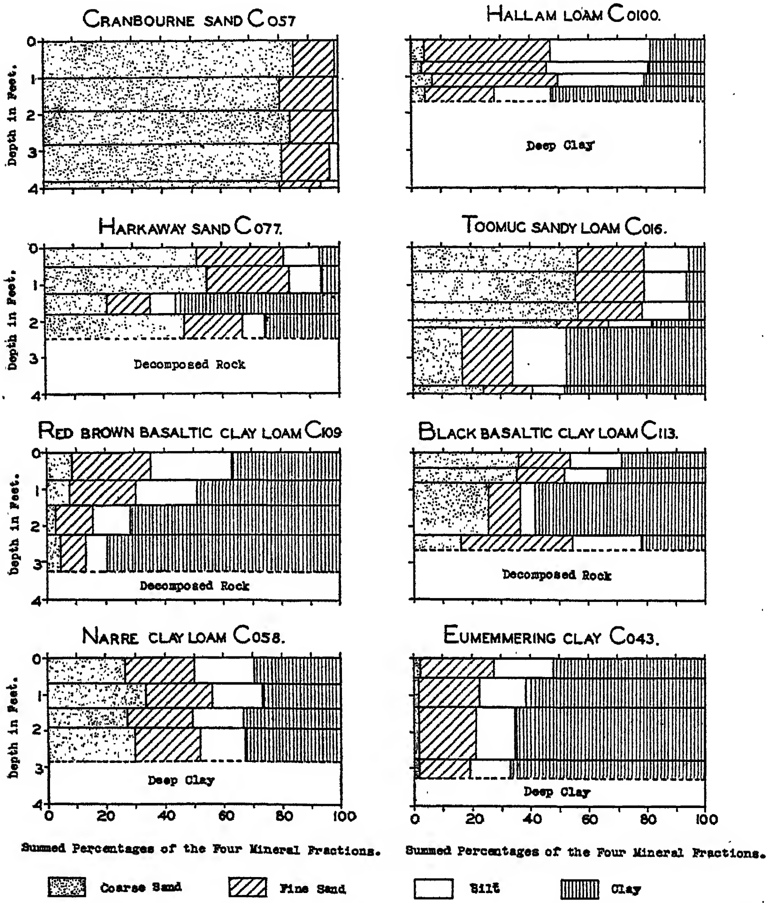


FIG. 8.—Mechanical composition showing in block form the summed percentages of the four mineral fractions throughout the profiles of eight major soil types. (Clay in Cranbourne sand is too small to show separately.)

relatively constant texture, or gradual change of texture through the profile, of the heavier Narre and Eumemmering types and the basaltic soils. The very sandy type, Cranbourne sand, also shows a large relative increase in clay in the subsoil, but the absolute quantity of clay is too small to be marked in the diagram. The ironstone gravel, which occurs above the clay horizon in many types, has been omitted from the diagram since it is not always present in the field. The diagram refers to the same material as is submitted to laboratory analysis—viz., the soil which passes a 2-mm. sieve.

Hallam loam is remarkably high in silt throughout the profile, a property which is evidently due to the silty nature of the Silurian rock from which its material has been derived. This siltiness is connected with the tendency of the surface soil to form clods, and with its erosiveness in the orchards. Harkaway sand, developed from the granodiorite, stands in marked contrast, with a low percentage of silt. This seems to indicate that the granodiorite hills have not played a considerable part in forming the material from which the silty soils of the plain were derived. Narre clay loam includes occurrences in which the subsoil is considerably heavier than in the two type samples.

A zone of maximum accumulation of clay can be seen in Cranbourne sand (C057), and on soils developed over the basalt (C113), the granodiorite (C077) and the Silurian sediments (C041).

The mechanical analyses of representative samples have also been plotted graphically in fig. 9, where the triangular method is

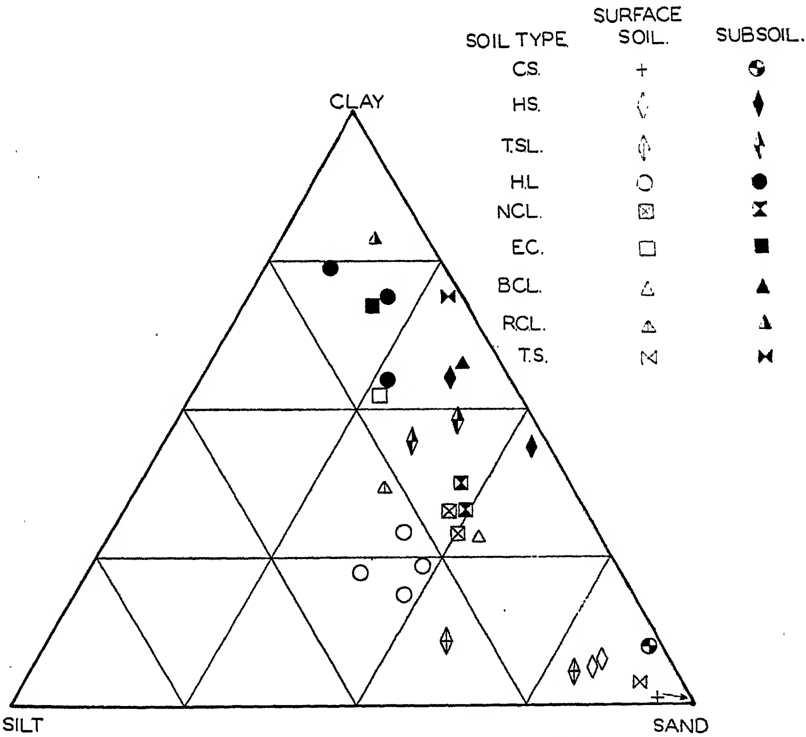


FIG. 9.—Mechanical analysis triangle. Distribution of mechanical compositions of samples of surface soil and subsoil of various soil types.

Explanation of Key.—C.S. Cranbourne Sand; H.S. Harkaway Sand; T.S.L. Toomuc Sandy Loam; H.L. Hallam Loam; N.C.L. Narre Clay Loam; E.C. Eumemmering Clay; B.C.L. Black Basaltic Clay Loam; R.C.L. Red Basaltic Clay Loam; T.S. Toomuc Sand.

adopted by which any mixture of sand, silt, and clay can be represented by a point. This shows in another way such facts as the contrast between surface and subsoil of the podzolic types (the latter lying much closer to the " clay " apex than the former) and the silty nature of Hallam loam, of which all four surface samples lie between the lines for 25 per cent. and 50 per cent. silt.

TABLE XIII.—MECHANICAL ANALYSES OF HARKAWAY SAND.

Soil No.	C013.			C077.			
Horizon	a†.	b.	c.	a.	b.	c.	d.
Depth (Inches)	0–10.	10–21.	21–32.	0–6.	6–15.	15–22.	22–30.
Coarse sand	59·2	61·3	47·6	49·7	54·1	21·3	47·5
Fine sand	22·2	22·3	6·7	28·5	27·9	14·6	19·5
Silt	9·8	8·5	2·5	11·4	10·6	8·6	7·9
Clay	7·5	6·6	43·9	6·0	5·9	55·3	24·8
Loss on Treatment*	3·0	1·7	1·5	4·1	1·3	1·3	1·1
Carbon	1·28	0·33	0·45	2·28	..	..	..
Nitrogen	0·11	0·02	..	..	..	..	..
Gravel (Field Sample)	..	..	..	..	11·1	2·3	8·5
pH	5·9	5·9	5·7	5·6	5·2	5·2	5·5
Comments	..	..	..	..	..	..	Decomposed Rock.

* This figure includes the organic matter destroyed by hydrogen peroxide in preliminary treatment, as well as the material dissolved at the next stage by dilute HCl.

† The letters *a*, *b*, *c* . . . as used here refer simply to the order of sampling of the various horizons, *a* being the first and *d* the fourth horizon to be taken in a profile. The letters are not meant to suggest any parallel with the technical meanings of *A*, *B*, and *C* horizons.

TABLE XIV.—MECHANICAL ANALYSES OF CRANBOURNE SAND.

Soil No.	C057.						
Horizon	a	b	c	d	e	f	g
Depth (inches)	0–12	12–23	23–34	34–46	46–60	60–64	64–66
Coarse sand	83·9	79·6	83·0	79·1	78·0	71·1	78·4
Fine sand	13·2	17·9	14·3	15·3	13·8	15·5	13·6
Silt	0·8	1·1	1·2	2·0	4·6	1·8	3·3
Clay	0·3	0·4	0·3	1·0	1·2	9·7	3·4
Loss on treatment	1·1	0·6	0·7	2·2	1·6	2·7	0·9
Carbon	0·89	0·42	..	1·05	1·05	..	..
Nitrogen	0·04	..	..	..	0·05	..	..
Gravel (field sample)	..	..	..	..	..	..	..
pH	4·9	4·7	4·3	4·6	4·9	..	4·8
Comments	..	..	..	..	Friable Ortstein	..	..

TABLE XV.—MECHANICAL ANALYSES OF TOOMUC SANDY LOAM.

Soil Number	C016.					
Horizon	*a*	*b*	*c*	*d*	*e*	*f*
Depth (Inches)	0–8	8–18	18–24	24–26	26–46	46–60
Coarse sand	55·6	55·2	56·7	49·3	16·9	23·9
Fine sand	22·8	24·2	22·6	18·3	17·0	17·3
Silt	14·8	14·7	16·0	14·7	18·3	11·2
Clay	5·5	6·1	5·5	18·3	47·8	48·6
Loss on treatment	3·5	1·8	1·3	1·3	1·9	1·1
Carbon	1·07	0·25	0·12	0·27	..	..
Nitrogen	0·06	0·02	..	..	..	..
Gravel (field sample)	..	..	..	..	..	..
pH	5·6	5·4	5·5	5·8	5·4	5·1

TABLE XVI.—MECHANICAL ANALYSES OF TOOMUC SANDY LOAM.

Soil No.	C092.						
Horizon	*a*	*b*	*c*	*d*	*e*	*f*	*g*
Depth (inches)	0–9	9–14	16–26	26–41	41–54	54–64	64–72
Coarse sand	14·5	23·4	16·3	21·3	9·0	12·2	16·6
Fine sand	40·0	39·8	23·8	29·6	26·7	24·5	21·4
Silt	29·6	25·3	17·3	16·0	19·6	20·6	22·1
Clay	10·2	9·7	41·9	32·2	44·7	42·0	39·9
Loss on treatment ..	3·9	1·8	1·3	1·1	1·1	0·8	0·9
Carbon	2·38	0·81	..	..	..	..	..
Nitrogen	0·15	..	..	..	..	..	..
Gravel (field sample) ..	..	..	..	..	..	..	..
pH	5·1	5·8	5·6	6·2	6·5	6·5	6·7

TABLE XVII.—MECHANICAL ANALYSES OF HALLAM LOAM.

Soil No. ..	C0100.				C041.				
Phase	Normal.				Silurian.				
Horizon ..	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*
Depth (inches) ..	0–7	7–11	11–15	15–20	0–8	8–12	12–18	18–30	30–44
Coarse sand ..	4·6	3·5	6·7	4·5	2·4	2·4	4·8	0·8	0·4
Fine sand ..	40·8	41·8	42·7	22·1	34·2	33·4	31·6	8·6	8·6
Silt	32·0	32·7	29·2	18·9	35·5	33·6	31·4	16·3	35·9
Clay	17·9	19·1	20·5	55·1	21·0	25·2	29·6	72·9	54·6
Loss on treatment	5·3	3·8	2·5	1·4	5·8	3·7	2·7	1·3	0·6
Carbon ..	3·61	2·11	..	..	3·36	1·60	..	..	..
Nitrogen ..	0·24	..	..	..	0·20	0·12	..	..	..
Gravel (field sample) ..	..	..	9·7	1·7	..	..	..	..	..
pH	5·3	5·6	5·6	5·3	4·7	4·4	4·5	4·7	4·6
Comments ..	..	..	..	Deep clay	..	..	..	..	Soft rock

TABLE XVIII.—MECHANICAL ANALYSES OF HALLAM LOAM.

Soil No.	C050.	C038.				
Phase	Normal.	Heavy.				
Horizon	*a*	*a*	*b*	*c*	*d*	*e*
Depth (inches)	0–8	0–6	6–11	11–16	16–21	21–32
Coarse sand	2·9	11·3	2·2	16·8	4·4	6·8
Fine sand	42·5	27·9	42·8	31·3	15·2	15·6
Silt	27·0	26·2	23·8	19·2	11·1	8·6
Clay	22·5	27·2	25·8	30·6	68·1	69·2
Loss on treatment ..	5·5	9·5	5·7	4·0	3·3	1·8
Carbon	3·15	3·55	1·30	0·83	0·93	0·65
Nitrogen	..	0·28	..	..	..	..
Gravel (field sample) ..	..	..	..	35·0	..	..
pH	5·5	5·4	5·5	5·9	5·7	5·6

TABLE XIX.—MECHANICAL ANALYSES OF NARRE CLAY LOAM.

Soil No.	C058.				C042.			
Horizon	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Depth (inches) ..	0–8	8–16	16–23	24–34	0–9	9–18	18–31	31–57
Coarse sand	24·9	32·4	26·7	29·3	20·6	25·2	23·5	24·3
Fine sand	22·0	21·3	21·6	21·1	23·9	23·1	23·1	22·1
Silt	19·3	16·7	17·2	15·5	17·8	17·2	15·9	15·6
Clay	27·1	25·6	32·5	32·0	30·0	31·9	35·1	36·7
Loss on treatment ..	4·7	3·2	2·3	1·9	5·5	2·6	1·4	1·0
Carbon	3·04	1·34	..	..	2·25	1·23	..	..
Nitrogen	0·19	..	..	..	..	..	..	..
Gravel (field sample) ..	..	..	..	..	..	..	..	..
pH	4·9	5·0	5·1	5·2	5·4	5·3	5·6	5·9

TABLE XX.—MECHANICAL ANALYSES OF TOOMUC SAND AND EUMEMMERING CLAY.

Soil No.	C059.			C043.			
Type	Toomuc Sand.			Eumemmering Clay.			
Horizon	*a*	*b*	*c*	*a*	*b*	*c*	*d*
Depth (inches)	0–14	14–32	32–37	0–6	6–16	16–33	33–42
Coarse sand	64·2	67·0	22·2	1·9	1·5	1·5	1·7
Fine sand	24·3	22·5	6·4	22·8	19·6	18·9	16·6
Silt	6·0	7·5	2·0	18·9	15·5	13·4	13·5
Clay	3·6	2·4	68·0	47·6	58·3	62·3	65·8
Loss on treatment ..	0·8	0·5	0·8	6·8	4·1	2·0	1·7
Carbon	0·84	0·17	..	3·46	2·05	1·06	1·47
Nitrogen	..	..	..	0·24	0·18	..	..
Gravel (field sample) ..	..	..	..	..	..	..	..
pH	4·1	5·5	5·0	5·5	5·8	6·6	6·7

TABLE XXI.—MECHANICAL ANALYSES OF RED AND BLACK SOILS ON BASALT.

Soil No.	C109.				C113.			
Phase	Red.				Black.			
Horizon	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Depth (inches) ..	0–9	9–17	17–27	27–39	0–5	5–10	10–27	27–32
Coarse sand	8·4	8·0	2·9	4·5	33·4	33·8	24·1	15·3
Fine sand	26·2	23·0	13·1	9·3	16·0	15·8	10·2	36·1
Silt	26·8	20·7	13·6	7·5	16·5	13·7	5·4	22·3
Clay	35·9	48·1	71·3	79·0	26·2	32·1	54·5	20·8
Loss on treatment ..	2·8	3·1	1·3	1·5	6·8	4·5	2·0	2·2
Carbon	3·91	1·72	1·31	0·66	4·22	..	..	..
Nitrogen	0·25	0·12	..	..	0·29	..	..	..
Gravel (field sample) ..	..	..	..	..	..	..	..	..
pH	5·8	6·3	6·1	6·1	5·4	5·5	6·5	7·0
Comments	..	..	..	..	..	..	..	Decomposing basalt

HYDROCHLORIC ACID EXTRACT.

Representative soils were extracted with boiling hydrochloric acid (as in the International method). Analyses of these extracts for potassium and phosphorus (expressed conventionally as K_2O and P_2O_5 respectively) are collected in Table XXII. Though the number of samples analysed from each type is small, some general relations may be pointed out from the figures.

Potassium.—The amount of potassium extracted from a soil by strong hydrochloric acid is generally related to the percentage of clay, and this is the case with these soils also. If we take 0.1 per cent. K_2O as the dividing line between fair and poor soils, the lighter types are low in potassium while the loams and clays (with one exception) have a good store. The high figure for the Silurian rock (C041e) is remarkable. This rock is well provided with potash-rich feldspars, and these constitute a valuable reserve against the impoverishment of the soil by leaching. The degree of availability of the HCl-soluble but non-exchangeable potassium of some of these soils is a matter of great interest. The sandier types (Harkaway, and especially Toomuc) are poor not only in immediately available potassium, but also in their reserves of the element.

The soils formed on the basalt are rather low in extractable potassium; however, the roots of plants growing on most of the soils can reach the layers of decomposing basalt, which contain primary minerals carrying rich reserves of potassium.

TABLE XXII.—POTASSIUM AND PHOSPHORUS DISSOLVED BY BOILING HYDROCHLORIC ACID.

—	—	Depth (inches).	K_2O	P_2O_5
Harkaway sand	C013*a*	0–10	·07	·019
	c	21–32	..	·010
Cranbourne sand	C057*a*	0–12	·012	·005
Toomuc sand	C059*a*	0–14	·015	·006
Toomuc sandy loam	C016*a*	0–8	·021	·016
	b	8–18	..	·004
	d	24–26	..	·006
	C006*a*	0–9	·06	..
	C092*a*	0–9	·05	·027
Hallam loam	C050*a*	0–8	·20	·028
	C0100*a*	0–7	..	·040
Hallam loam (silurian phase) ..	C041*a*	0–8	·24	·046
	b	8–12	·24	·015
	e	30–44	·47	·010
Narre clay loam	C058*a*	0–8	·05	·026
	C042*a*	0–9	..	·028
Eumemmering clay	C043*a*	0–6	·21	·059
	b	6–16	·22	·043
	C074*a*	0–10	·35	·113
Basaltic soils—				
Black	C102*a*	0–6	·09	..
	C103*a*	0–6	·11	..
	C113*a*	0–5	..	·038
Red	C104*a*	0–6	·07	..
	C106*a*	0–7	·21	..
	C108*a*	0–8	·06	·140
	b	8–20	·03	·130
	C109*a*	0–9	..	·053
	c	17–27	..	·041

Phosphorus.—Most of the soils analysed illustrate the general poverty of Victorian soils in phosphorus. Of the non-basaltic types, only Eumemmering clay reaches as high as 0.05 per cent. P_2O_5, and one sample of this type exceeds 0.1 per cent. The lighter types are poor or very poor, and even the two best samples of Hallam loam have been given unusual amounts of additional phosphate. The phosphorus content of the Silurian rock stands in marked contrast to the figure for potassium. The basaltic types are interesting. The deep, mature soils (C109, C113) have lost most of their original supply, but the immature sample (C108), which contains still decomposing basalt, is fairly rich in phosphorus. Figures of the order of 0.1 per cent. P_2O_5 have been obtained for several other soils on the basalt in this area, and these soils appear to be generally richer than the non-basaltic types.

Organic Matter.

Organic carbon (Table XXIII) was estimated by Tiurin's rapid approximate method (using the figure 1 ml. normal oxidizing agent equals 3.3 mg. carbon); the total organic matter may be calculated by multiplying these figures by 1.73. The figures range from low values for the sandiest types to high values for the basaltic types and Eumemmering clay. The total organic matter in some basaltic soils exceeds 10 per cent.—a figure which is evidently due to the high chemical fertility of these soils as well as to their moisture-retaining capacity; both of these factors

Table XXIII.—Distribution of Carbon Content of Surface Soils (by Tiurin's Method).

Soil Type.	Carbon, Percentage.										
	Mean.	0·5–1·0.	1·0–1·5.	1·5–2·0.	2·0–2·5.	2·5–3·0.	3·0–3·5.	3·5–4·0.	4·0–5·0.	5·0–6·0.	6·0–7·0.
Harkaway sand	1·6	..	2	..	1	..	..	..	..	..	..
Cranbourne sand	1·1	1	1	..	..	..	..	..	..	..	..
Toomuc sand	0·8	1	..	..	..	..	..	..	..	..	..
Toomuc sandy loam	2·2	..	1	..	..	1	1	..	..	..	..
Hallam loam	3·4	..	..	..	..	..	2	2	..	..	..
Narre clay loam	2·7	..	..	..	1	..	1	..	..	..	..
Eumemmering clay	4·4	..	..	..	..	..	1	..	..	1	..
Red-brown basaltic clay loam ..	5·3	..	..	..	..	..	..	1	1	2	1
Black basaltic clay loam ..	4·5	..	..	..	..	1	..	..	2	..	1

increase the annual addition of plant residues to the soil, and hence lead to a high content of humus. The relatively high figures for the samples of Hallam loam are interesting, and would hardly be expected from their pale appearance.

These samples, as might be expected, are also rather high in organic nitrogen, but the improvement in fertility caused by the growth of subterranean clover indicates that the quality of this nitrogen for plant growth is not high.

Salt Content of Soils.

Normal Soils.—The soils of the area are generally low in soluble salts, as might be expected from the nature of the climate. Several representative samples were analysed both for total salt (conductometrically) and for chloride.

The majority of surface soils contain less than 0.01 per cent. of sodium chloride. A few figures are collected in Table XXIV which shows that salt reaches moderate amounts only in a few deep subsoils.

Saline Patches.—The surface 6 inches of the bare saline patches contain as much as 0.8 per cent. of sodium chloride, with an average of 0.44 per cent. for nine samples. The lower layers are also saline, but the highest concentrations are invariably found on the surface; this indicates that water is held up by the clay subsoil in the second foot long enough for capillary rise and evaporation at the surface to be an important factor. The two series of samples quoted in Table XXV (C047 to C045, C050 and C051) are very interesting in showing how localized the salt is; a chain away from the edge of a bare patch the salinity is down to normal levels.

Analyses of the extracted salt show that sodium and chloride are the predominant ions, and magnesium and sulphate occur in appreciable amounts. The salt, in fact, approximates in composition to sea-salt.

Table XXIV.—Chloride in Normal Soils, Reckoned as Sodium Chloride.

Soil Type.	Sample Number.	Depth. (inches)	NaCl, parts per 100,000.
Toomuc sandy loam	C016*e*	26–46	10
	C092*c*	16–26	20
	C092*g*	64–72	100
Hallam loam	C038*a*	0–6	10
	C038*d*	16–21	10
Bunemmering clay	C043*a*	0–6	0
	C043*b*	6–16	20
	C043*c*	16–33	100
	C043*d*	33–42	170
	C061*a*	0–6	10
	C061*d*	25–32	80
	C074*c*	20–36	10

All the above samples have a clay texture except CO38*a*. Many figures for lighter soils have been omitted, all being low.

TABLE XXV.—CHLORIDE IN SALINE SOILS, RECKONED AS SODIUM CHLORIDE.

Soil Type.	Sample Number.	Depth. (inches)	Plant cover.	NaCl, parts per 100,000.
Toomuc sandy loam .. .. (Series within one chain)	C047*a*	0–8	Normal pasture	20
	C046*a*	0–6	Plantago	80
	C045*a*	0–8	Bare	260
	c	12–15	..	70
	e (clay)	28–36	..	60
Hallam loam .. .. (Series within one chain)	C050*a*	0–8	Normal pasture	10
	C051*a*	0–6	Bare	760
Toomuc sandy loam	C044*a*	0–7	Bare	530
	b	7–12	..	260
	c	12–18	..	160
	C065*a*	0–6	Bare	430
	b	6–15	..	100
	c	15–17	..	50

pH VALUES.

Reactions were determined by means of the quinhydrone electrode, using equal weights of soil and water. The distribution of the pH values of the surface, subsurface, and subsoil is shown in Table XXVI. Considering surface soils first, it will

TABLE XXVI.—DISTRIBUTION TABLE OF pH VALUES (QUINHYDRONE ELECTRODE).

—	Mean.	3·0–3·5	3·5–4·0	4·0–4·5	4·5–5·0	5·0–5·5	5·5–6·0	6·0–6·5	6·5–7·0	7·0–7·5
Harkaway sand—										
Surface	5·7	..	..	..	..	1	3	..	..	..
Subsurface	5·6	..	..	..	..	1	1	..	..	..
Subsoil	6·0	..	..	..	..	..	2	..	1	..
Cranbourne sand—										
Surface	4·4	1	..	..	1	1	..	..	..	..
Subsurface	4·3	1	..	..	2	..	..	..	..	..
Subsoil	4·5	..	1	..	1	1	..	..	..	..
Toomuc sand—										
Surface	4·1	..	..	1	..	..	..	..	..	..
Subsurface	5·1	..	..	..	..	1	..	..	..	..
Subsoil	5·3	..	..	..	..	1	..	..	..	..
Toomuc sandy loam—										
Surface	5·4	..	..	..	..	4	5	..	..	..
Subsurface	5·5	..	..	..	..	2	2	..	..	..
Subsoil	5·9	..	..	..	..	1	2	..	1	..
Hallam loam—										
Surface	5·4	..	..	..	3	3	4	1	..	..
Subsurface	5·4	..	..	..	1	2	1	1	..	..
Subsoil	5·3	..	..	..	1	..	2	..	..	..
Saline soils— (These all belong to above two types)										
Surface	4·8	..	..	2	4	..	..	..	1	..
Subsurface	5·5	..	..	..	2	..	2	..	1	..
Subsoil	5·6	..	..	..	..	2	1	..	..	..
Narre clay loam—										
Surface	5·1	..	..	..	2	2	..	..	..	..
Subsurface	5·3	..	..	..	..	3	..	..	..	..
Subsoil	5·4	..	..	..	..	2	1	..	..	..
Eumemmering clay—										
Surface	5·3	..	..	..	..	3	1	..	..	..
Subsurface	5·9	..	..	..	..	..	1	1	..	..
Subsoil	5·8	..	..	..	1	..	1	..	1	..
Red-brown basaltic clay loam—										
Surface	5·6	..	..	..	..	2	5	..	..	..
Subsurface	5·7	..	..	..	..	1	4	1	..	..
Subsoil	6·1	..	..	..	..	..	1	1	1	..
Black basaltic clay loam—										
Surface	5·5	..	..	..	..	1	2	..	..	..
Subsurface	6·2	..	..	..	..	..	1	2	..	..
Subsoil	6·6	..	..	..	..	..	..	2	1	1

be seen that acidic reactions are the rule throughout, only one normal surface soil reaching even to pH 6; and this is so in spite of the light dressings of lime which have been applied to some properties. The majority of the samples of the commonest types lie between 5 and 6, with a large number of readings more acid than 5.5. The lightest type—Cranbourne sand—is the most acidic of all throughout the profile, and is the only type on which acidity appears to limit the growth of plants—though, of course, only plants which are fairly tolerant of acidity are widely grown in this district in any case.

There is a tendency towards a higher pH value in the lower layers of some soil types, a tendency which is most marked in the black basaltic type.

The saline soils have been grouped separately; they are definitely more acidic than the normal soils of the same type, with the exception of one which is more alkaline than the normal soils. It is possible that these soils owe their acidity to recent accession of salt, in conformity with the general rule that the pH of a soil suspended in a salt solution is lower than in pure water; while the more alkaline sample may represent a more mature phase of the interaction of soil with a sodium salt.

Exchangeable Cations.

The four main elements extracted by leaching with normal ammonium acetate at pH 7 are recorded in Table XXVII. Those

Table XXVII.—Exchangeable Cations.

Soil Type.	Sample No.	Depth. (in.)	Exchangeable Cations. Percentage of Total. Ca.	Mg.	Na.	K.	Total in milliequiv. per 100 gm. Oven-dry Soil.	pH.	Percentage Clay.
Harkaway sand	C013*a*	0–10	65	28	2	5	4·3	5·9	7·5
Toomuc sandy loam—									
Normal Phase	C016*a*	0–8	52	37	8	3	1·9	5·6	5·5
	C016*b*	8–18	58	32	7	3	0·9	5·4	6·1
	C016*e*	26–46	7	81	11	1	10·2	5·4	47·8
	C092*a*	0–9	55	38	5	2	4·2	5·1	10·2
	C092*c*	16–26	18	66	15	1	12·9	5·6	41·9
Saline phase	C045*a*	0–8	18	54	25	3	2·1	4·5	..
	C045*e*	28–40	10	64	25	1	6·1	5·4	..
Hallam loam—									
Normal phase	C0100*a*	0–7	58	37	3	2	9·2	5·3	17·9
	C0100*d*	15–20	19	71	9	1	15·7	5·3	55·1
Heavy phase	C038*a*	0–6	45	50	3	2	12·1	5·4	27·2
	C038*d*	16–21	23	70	6	1	18·8	5·7	68·1
Silurian phase	C041*a*	0–8	55	38	5	2	7·3	4·7	21·0
Narre clay loam	C058*a*	0–8	36	58	5	1	15·2	4·9	27·1
Eumemmering clay	C043*a*	0–6	42	52	4	2	23·7	5·5	47·6
	C043*b*	6–16	33	58	7	2	26·1	5·8	58·3
	C043*d*	33–42	25	59	14	2	30·1	6·7	65·8
	C074*a*	0–10	37	57	4	2	19·6	5·1	..
	C074*c*	20–36	26	67	5	2	21·9	4·9	..
Red-brown basaltic clay loam	C109*a*	0–9	53	39	3	5	13·4	5·8	35·9
	C109*c*	17–27	31	63	5	1	11·2	6·1	71·3
	C109*d*	27–39	26	66	6	2	10·5	6·1	79·0
Black basaltic clay loam ..	C113*a*	0–5	54	42	3	1	19·1	5·4	26·2

surface soils which are relatively low in clay are poorly supplied with these four elements; but even the heavier soils have not a very good supply, partly because of their acidity—in other words, because acidic hydrogen takes up a large proportion of the soil's capacity for holding cations. Most of the subsoils (which are high in clay) contain more of the exchangeable elements than the surface soils, though the red basaltic type C109c and d) is remarkably low in this respect. Such a low capacity for holding cations is a feature of highly ferruginous soils in other parts of the world.

The available *calcium* in the soil may be taken as equivalent to the exchangeable calcium. Among the podzolic types of soil (Harkaway, Toomuc, Hallam) this is always less than 0.15 per cent. of "lime" (CaO). If we accept G. W. Robinson's opinion (9) that lime is needed on all soils with less than 0.25 per cent. of exchangeable calcium reckoned as CaO (or 9 milli-equivalents per cent.) then all these types are deficient except the Eumemmering clay and the black basaltic type.

The figure for exchangeable *potassium* gives useful information as to the amount of available potassium. Here again the podzolic types are poorly equipped. Harkaway sand, containing reserves of primary minerals which keep up the supply, is probably safe against potassium deficiency, but the Hallam and Toomuc types are poor. Sample C016 was taken from a property which was heavily cropped with oats in former years, and on which there is reason to believe that the present pasture is deficient in potassium. The exchangeable potassium in the surface 8 inches corresponds to only 50 lb. of the element per acre.

Relative Importance of the Four Elements.—The surface soils contain calcium and magnesium in roughly equivalent amounts. The subsoils, however, contain magnesium in predominant amounts, even up to 80 per cent. of the total exchange capacity of the soil, while calcium drops to one-third, or even less, of the magnesium. Sodium also increases in the subsoil and reaches the same order as calcium in two normal samples. In a very poor saline soil sodium reaches 25 per cent. of the total, and calcium falls to third place.

This occurrence of magnesium- or magnesium-sodium-clays is common in Victoria, and appears to be related to the incidence of cyclic salt already referred to (p. 195). The uptake of calcium and magnesium by the native trees and grasses which formerly covered the country might also have an interesting connexion with these figures for exchangeable ions.

Composition of Clay Fractions.

The material of less than 0.001 mm. diameter was isolated from selected soils and the results of a complete analysis are collected in Table XXVIII. Among the podzolic types the clays of the grey surface soils are highly siliceous, while those of the yellowish subsoils are relatively higher in aluminium and iron. The red basaltic soil is much less siliceous, both in the surface and in the subsoil. The high concentration of iron in the surface clay of this type is interesting. The high content of titanium in the surface clays of both types is striking; the parent rocks are also high in titanium.

Table XXVIII.—Chemical Composition of Clay Fractions Below 0.001 mm. Diameter.

Soil Types.	Depth. (in.)	Percentage Composition.				Molecular Ratios.	
		SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	$\frac{SiO_2}{Al_2O_3}$.	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$.
Hallam loam, grey surface—							
C038*b* ..	6–11	43·4	19·9	9·4	7·8	3·65	2·81
C099*a*, *b* (Composite)	0–13	48·8	24·6	5·2	5·0	3·28	2·90
Hallam loam, yellow subsoil—							
C038*e* ..	21–32	41·3	25·2	10·9	2·5	2·73	2·14
C092*c* ..	16–26	42·5	27·0	9·5	1·6	2·63	2·15
Red basaltic—							
C109*a* ..	0–9	35·3	24·3	16·4	5·4	2·44	1·70
C109*d* (Composite)	27–39	37·7	32·5	9·3	1·0	1·95	1·67

Mineralogy of "Fine Sand" Fractions.

The "fine sand" fractions (i.e., particles of diameter between 0.2 and 0.02 mm.) were isolated from selected samples, and the following information has been supplied by Miss A. Nicholls, M.Sc., who kindly examined them for their minerals.

Harkaway sand (on granodiorite).—Quartz predominant. Plagioclase and orthoclase common as large and fresh fragments. Hornblende rare. Mr. G. Baker has kindly provided the following information from a Rosiwal analysis of the granodiorite itself:—Quartz, 24 per cent.; orthoclase, 17 per cent.; plagioclase, 39 per cent.; biotite, 15 per cent.; hornblende, 5 per cent. Apatite also is present.

Cranbourne sand.—Almost pure quartz, feldspars absent.

Toomuc sandy loam.—Quartz predominant, a few grains of decomposed plagioclase and orthoclase

Hallam loam and Eumemmering clay.—Similar to Toomuc sandy loam.

These four soils, derived from unconsolidated sediments, contain only poor reserves of primary minerals.

Hallam loam (Silurian phase).—Richer in orthoclase and plagioclase than the four types just mentioned; especially as the parent rock is approached. Hornblende, apparently wind-blown, occurs in surface of both samples, in appreciable amounts.

Black basaltic soil (C113b).—This is a "mature" soil; most of the original minerals of the basalt have been decomposed and the fine sand contains mainly quartz. Plagioclase is less important than in the last-mentioned soil. Magnetite is common. A few grains of augite are present, probably due to the survival of a few "floaters" of rock through the profile.

The red and black soils formed on basalt through Gippsland are usually similarly devoid of the rich primary minerals which the original basalt contained.

VII. Botanical Surveys.

Several different associations of plants occur on the various types of land in this district. We are greatly indebted to Miss Y. Aitken, M.Agr.Sc., for carrying out a botanical survey of some of these associations, the results of which are given below:—

WOODED SLOPES OF HILL COUNTRY NORTH OF BEACONSFIELD. SOIL TYPES, HARKAWAY SAND ON GRANODIORITE AND RUGGED SILURIAN COUNTRY.

The bush in this area is an association of trees, mainly Messmate (*Eucalyptus obliqua*), Peppermint (*E. australiana*), and Blackwood (*Acacia melanoxylon*), with scattered woody shrubs and tussock grasses. The trees are about 5 yards apart in the upper sections of the slopes, but they and the other growth become more dense lower down (cf., pl. XII, fig. 2), and begin to include more hydrophilic species such as *Melaleuca squarrosa* (Swamp Paperbark), rushes, &c. The amount of bare space in a square-foot quadrat is about 80 per cent. on the upper slopes, and about 70 per cent. on the lower slopes. The ground is covered mostly by dead leaves of Peppermint and Messmate. No distinct difference is evident between the flora from each type of soil on similar slopes. However, of the two species of tussock grasses, *Poa caespitosa* and *Danthonia pallida*, the former tends to be characteristic of the granodiorite and the latter of the Silurian country. The bush described here is typical of large areas, but its composition may well have been affected by the frequent fires since white settlers arrived.

SANDHILLS NEAR CRANBOURNE. (Soil type, Cranbourne Sand).

(*a*) *Virgin Scrub.*—The original vegetation of the deep sand, here named Cranbourne sand, is a xerophytic scrub association, of woody shrubs and some scattered trees. Typical quadrats show that about 50 per cent. of the ground is bare. The commonest tree is Peppermint (*E. australiana*), and Manna gum (*E. viminalis*) occurs occasionally as a stunted form.

The shrubs are much less varied than in the hilly country just described, and range up to 6 feet high. They are chiefly Silky Teatree (*Leptospermum myrsinoides*), with Wedding bush (*Ricinocarpus pinifolius*), Bundled Guinea flower (*Hibbertia fasciculata*), a species of Bush pea (*Pultenea* sp.), and Broom Spurge (*Ampera spartioides*) frequent.

In places where the scrub has been partly cleared, Bracken (*Pteridium aquilinum*) and Wild Parsnip (*Didiscus pilosa*) have formed closed communities.

(*b*) *Cleared land.*—Part of this area has been cleared, and is now an open association of Bracken, Sorrel (*Rumex acetosella*) and Yorkshire Fog (*Holcus lanatus*) with some Barley Grass (*Hordeum murinum*) and Silver Grass (*Festuca bromoides*), and Bent Grass (*Agrostis* sp.). In a depression, the greater moisture has made possible a complete cover of annual clovers (*T. recumbens, T minus*), White clover (*T. repens*), and Yorkshire Fog.

TEA-TREE SWAMPLAND. (Soil type, Narre clay loam.)

The slope described in the last paragraph descends to a tongue of tea-tree swamp. This land is covered by Swamp Paperbark (*Melaleuca ericifolia*) about 8 feet in height. This scrub is so dense that very few other plants survive. Tall sedge (*Carex appressa*) occurs near the edge of the scrub.

Where the scrub has been cleared the land carries a moderately open association of grasses, mainly native, and some herbs. Small tussocks of *Poa caespitosa* are the most prominent feature.

UNIMPROVED NATIVE PASTURE. (Soil types, Hallam loam, Toomuc sandy loam.)

The gently sloping land to the south of the Highway was formerly covered with species of Eucalyptus. Where the timber has been removed but the pasture has not been improved, this land carries to-day a characteristic association of native grasses. Such an association is found for example on the drier ground on the edge of the swamp just described. This is characterized by:—Kangaroo grass (*Themeda triandra*), various Wallaby grasses (*Danthonia semi-annularis, D. pilosa, D. penicillata*), and introduced plants, mainly Yorkshire Fog, Sweet Vernal grass (*Anthoxanthum odoratum*), Flatweed or Cat's ear (*Hypochaeris*

radicata) and *Plantago coronopus.* Kangaroo and Wallaby grasses are typical of this better drained land. while *Poa caespitosa* is dominant on the swampy flats

Special Areas.

(*a*) *Very Acid Areas.*—In a cleared field of Cranbourne sand the normal pH ranges from 4 to 5, and the plant association consists of Bracken, Sorrel, Yorkshire Fog, Subterranean Clover, and Hair and Silver grass. Some highly acid patches occur, however, with a pH value close to 3.5; one sample even recorded pH 3.1. These patches carry a Sorrel association which is pure apart from several plants of Hair grass (*Aira praecox*). Even these tolerant plants, however, form such a sparse association that 90 per cent. of the ground is bare.

(*b*) *Saline Areas.*—A number of saline patches occur at the foot of slopes. The land here consists of quite bare areas alternating with pure stands of Buck's horn Plantain (*Plantago coronopus*). Towards the edge of such patches, Cat's ear, Couch (*Cynodon dactylon*), love grass (*Eragrostis diandra*), Sweet Vernal grass, and Wallaby grass occur in turn. The Plantain is very dwarfed compared with its growth in normal pastures, and occurs in a density of about 40 plants per 6-inch square. The high tolerance of this plant towards salt is well known.

Acknowledgments.

We wish to acknowledge the valuable assistance of Miss M. Sharman and Mr. G. Ogilby in the preparation of the maps and other blocks. We are also indebted to Mr. A. Pearson, M.A., for collection of some of the material published here.

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Explanation of Plates.

Plate IX.

Types of country in the Berwick district. (Photographs by B. A. Pearl.) Upper left—General view of plains from a basaltic hill. Upper right—Apple orchard on lower slopes in rugged Silurian hills. Lower left—Tongue of Narre clay loam carrying tea-tree. Lower right—Cleared basaltic hills in background, uncleared Silurian hills to right (looking north from Berwick).

Plate X.

Fig. 1.—Hallam loam on Silurian mudstone. The wooden handle is 14 inches long.

Fig. 2.—Harkaway sand, showing the very light sub-surface layer, resting on sandy clay.

Fig. 3.—Gully eroded, following the scooping out of a drain.

Plate XI.

Fig. 1.—House on Hallam Valley settlement.

Fig. 2.—Salt patch at foot of slope. The native grasses give way to Plantago.

Fig. 3.—Head of gully shown on preceding plate.

Fig. 4.—Salt patch at foot of a Silurian ridge. The bare ground has been badly eroded.

Plate XII.—Aerial Photographs.

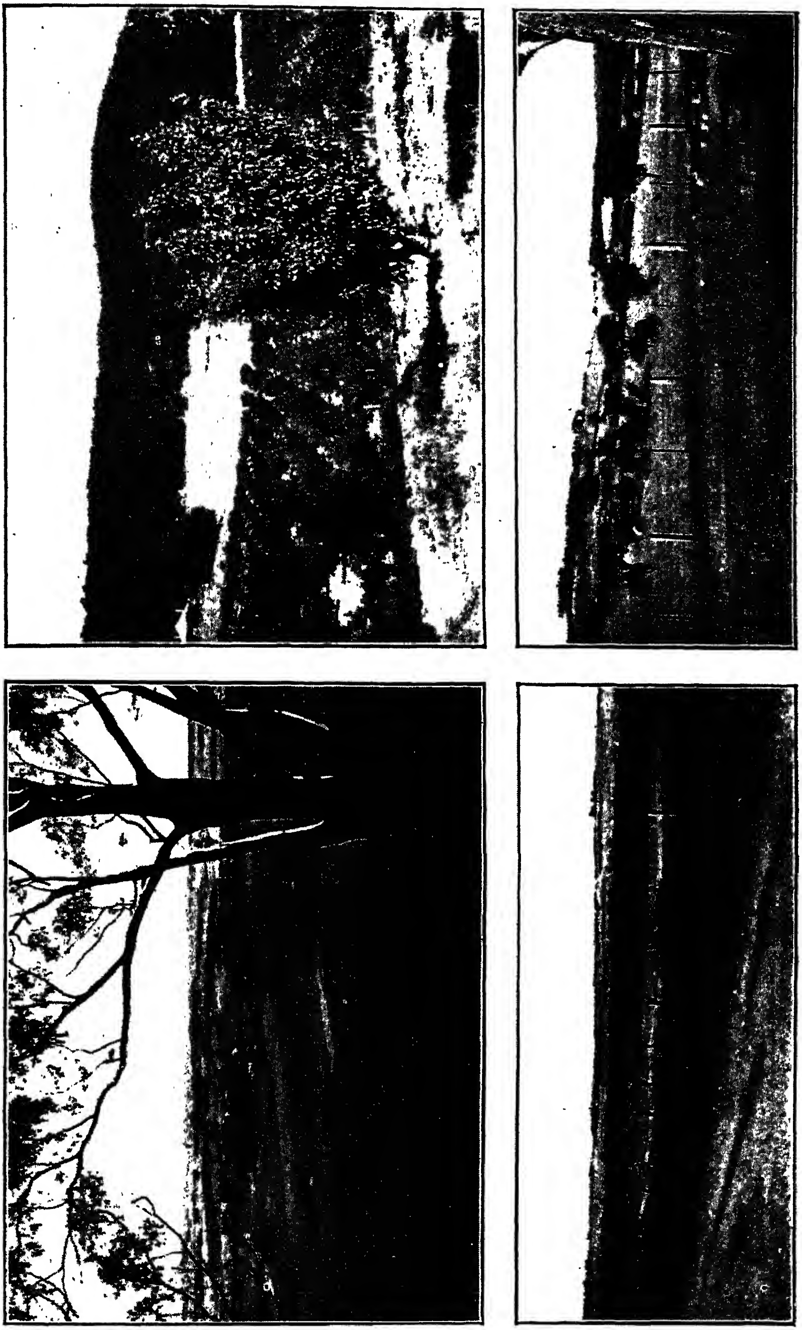
Fig. 1.—Bare patches, affected by salt, at the foot of parallel ridges of Silurian rock. The land between these patches is flat and poorly drained.

Fig. 2.—Orchard in rugged Silurian hills. The lighter patches in the timbered country are the ridges, the darker patches are the valleys which are more densely covered. The effect of erosion in the orchard is shown by the healthier trees in the basin.

Fig. 3.—Highly improved pasture (white clover and perennial rye grass) in the upper centre, native pasture on the other side of the fence. The light patch in the improved property is being cultivated in preparation for a summer crop.

Fig. 4.—The dense vegetation is silver tea-tree growing on Narre clay loam in a depression along a watercourse. The open timber just to the west is "peppermint" growing on the Silurian phase of Hallam loam on rising land.

Fig. 5.—A similar transition to that in fig. 4 showing on cultivated soil after rain. The dark soil is Eumemmering clay, the light soil is the Silurian phase of Hallam loam. There are some bad saline patches on the latter type, which have been eroded to a depth of 9 inches (plate XII, fig. 4).

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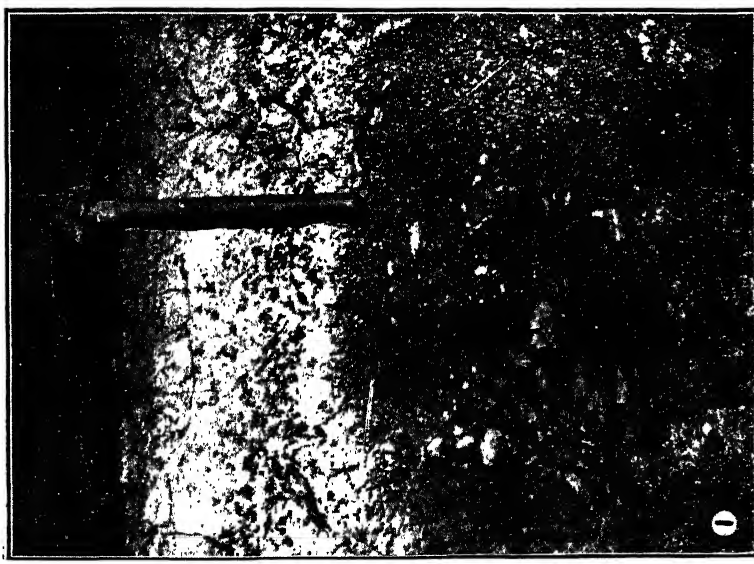
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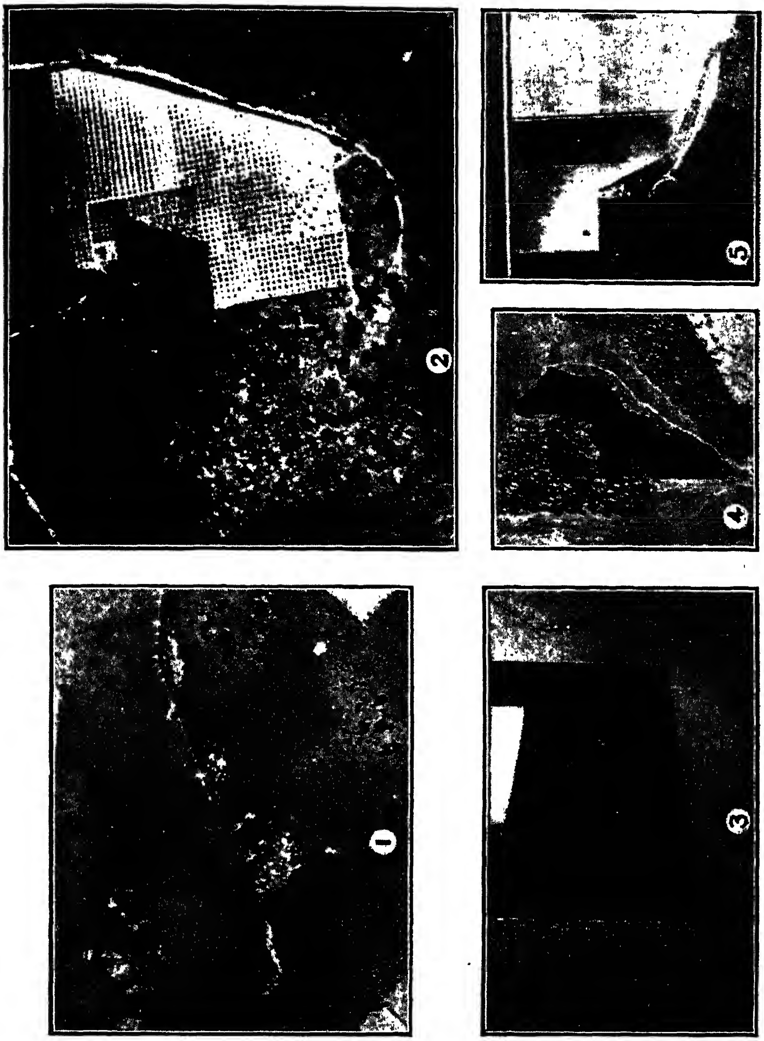

[PROC. ROY. SOC. VICTORIA, 52 (N.S.), Pt. II., 1940.]

The Silurian Rocks of Melbourne and Lilydale: A Discussion of the Melbournian-Yeringian Boundary and Associated Problems.

ART. XI.—By EDMUND D. GILL, B.A., B.D.

[Read 14th September, 1939; issued separately 1st July, 1940.]

Contents.

Silurian Type Areas.

In 1903 Professor Gregory (7) divided the Silurian rocks of Victoria into two series, namely:

2. Yeringian (Younger).
1. Melbournian (Older).

In 1933 Thomas and Keble (17) introduced a third and older division, and the succession now generally recognized (4) is:

3. Yeringian.
2. Melbournian.
1. Keilorian.

The Keilorian is typically developed near Keilor, north-west of Melbourne. These rocks were included by Gregory in the Melbournian. Melbourne is the type area for the Melbournian. Gregory specially mentioned the fossil localities at Moonee Ponds Creek and South Yarra (Improvement Works). I propose that, by reason of priority of systematic description in McCoy's "Prodromus" (12) and other publications, the Moonee Ponds Creek locality be regarded as the Melbournian Type Area, in the restricted sense. Such a distinction is needed as a basis for the further subdivision which the Melbournian requires.

In dealing with the Yeringian rocks, the beds are still called "Silurian" (although Ripper (16) and Hill (8) have recently suggested a Devonian age for the Cave Hill limestone), the reason being that this paper is concerned with the succession of the strata and not a discussion of their age.

The Lilydale district is the type area for the Yeringian. This area comprises the following original fossil localities:

(*a*) Cave Hill (bluish limestone).
(*b*) Wilson's (fawn shale).
(*c*) Hughes's Quarry (chiefly fawn sandstones).
(*d*) "Yering, near Coldstream" (yellow and purplish shales).
(*e*) Hull Road (reddish and occasionally white shales).

This number of localities has been greatly multiplied by recent investigations. The question of a restricted type locality is a difficult one because the limestones and shale faunules are almost mutually exclusive. I propose therefore that two restricted type localities be recognized, one for the limestones and one for the shales. Further, that these be Cave Hill and Hull Road respectively. Hull Road is the nearest of the original localities to Cave Hill, being separated from it by only 275 yards. A detailed survey of the area has shown that the two series of strata are conformable, there being regular easterly dips in between.

The Melbournian—Yeringian Boundary.

A problem awaiting solution is the precise location of the boundary between the Melbournian series and the Yeringian series. The chief difficulty lies in the fact that so many of the strata between Melbourne and Lilydale have so far yielded no fossils. The occasional discovery of new fossil localities, however, gives some hope of the needed palaeontological data being forthcoming even yet.

At Croydon there is a prominent scarp running north to the River Yarra. Jutson (10) described this as a fault scarp. It has generally been considered that in all probability this is the boundary between the Melbournian and Yeringian, the latter being faulted down against the former. Hills (9) on physiographic grounds denied the presence of this fault. The author, after a fairly detailed examination of the area, has reached the same conclusion. During the examination of the area under discussion, Yeringian fossils were found west of the so-called fault-line, proving that whether there be a fault there or not, it is not the boundary between the Melbournian and the Yeringian. These fossils were found on Yarra Road, which proceeds north to Wonga Park, at a location on the west side of the road in a cutting immediately south of Bryson Road (Military Map reference 298, 444). They were found in a whitish quartzitic sandstone having light touches of red ferruginous stain. The rock is often considerably pitted on the bedding planes. This is due, apparently, to the leaching away of calcareous organic fragments. The determining fossils are:

Phacops fecundus McCoy non Barrande.

Anoplia, sp. nov.

The first fossil is sometimes confused with *Phacops sweeti* Eth. fil. and Mitch. (6). It is common in the beds underlying the edge of the Older Basalt on the western side of Lilydale (i.e. Melbourne Hill, Lilydale), and has been collected from Ruddock's Quarry. The second fossil is a smooth Chonetoid brachiopod (described in MS) which is common in the Yeringian strata

and particularly so at Ruddock's Quarry. The genus is new to Australia and is found in the Yeringian of the Kinglake District as well as at Lilydale.

It is relevant to record also three new fossil localities which help to link up the Yarra Road locality with the well-known Lilydale localities. Fossils of Yeringian affinities have been collected from:

(1) The corner of the Melbourne-Lilydale highway and Edward Road, called "The Black Springs". The strata from which the fossils were collected outcrop in the gutter on the north side of the main road, under the edge of the Older Basalt residual. The following were obtained at this point:

(*a*) In fawn shale—

Anoplia, sp. nov.
Atrypa reticularis (Linnaeus).
Bellerophon sp.
Leiopteria sp. (found also at Ruddock's Quarry).
Orthonota sp.

(*b*) In micaceous sandstone—

Lingula sp. (same form as from Hull Road, Lilydale).
cf. *Loxonema* sp.
Fronded crinoid stem (similar to one collected from Ruddock's Quarry).

I suggest that this locality be known as "Black Springs". It is so marked on the Military Map. Definite locality names are being suggested in order to prevent the use of a number of names for the same place. This has happened in the past and caused confusion. The localities are also shown on the map which accompanies this paper (fig. 1).

(2) The second new fossil locality is in a cutting on Manchester Road at the top of a hill 500 yards south of the Black Springs corner. Among the fossils from the greyish-brown shale of this site are:

Anoplia, sp. nov.
Nucleospira australis McCoy.
Orthoceras sp.

I suggest that this locality be known as "Manchester Road".

(3) The third new locality is in a cutting on the main Melbourne-Lilydale highway between North Croydon and Black Springs. The cutting is ¾ mile east of Brushy Creek, on the north side of the road. This collecting place yielded:

Chonetes bipartita Chapman.
Dalmanella elegantula (Dalman).
Phacops (*Acastina*), sp. nov. (?)

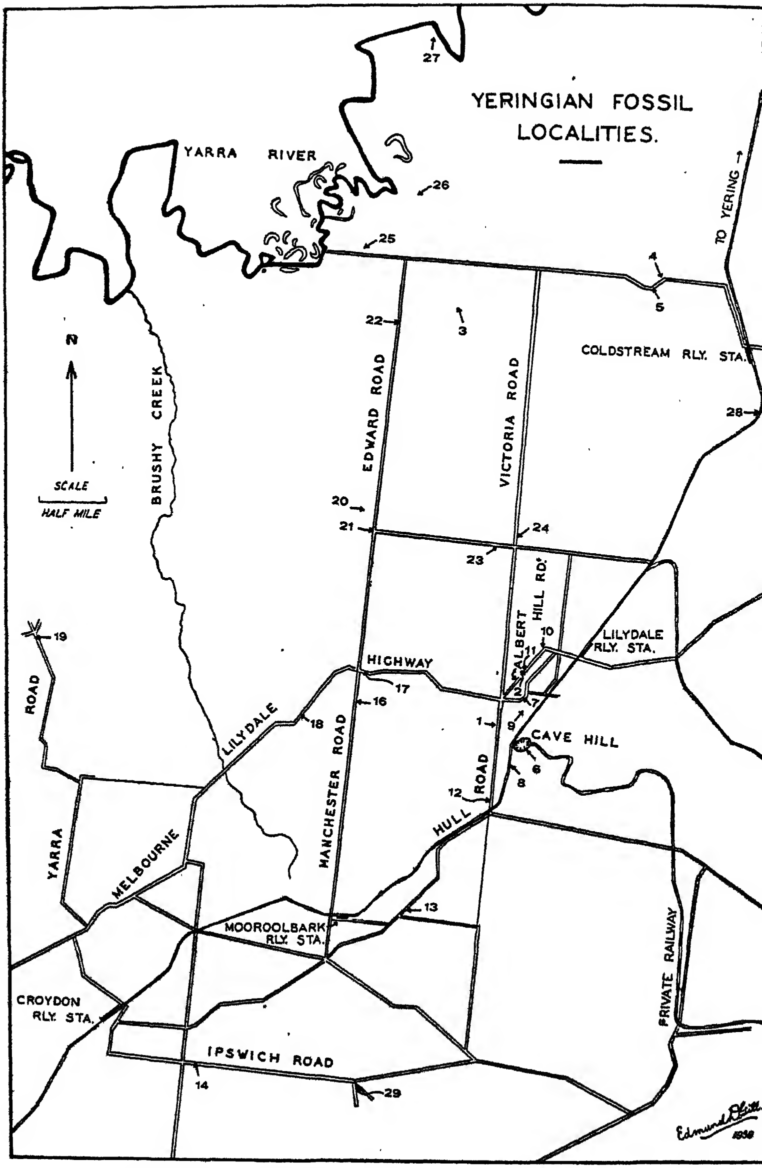

FIG. 1.—Map of Lilydale–Croydon Area showing Yeringian Fossil Localities.

Acastina Reed (15) is a sub-genus of trilobite not recorded from Australia before. A good specimen has been found among the fossils collected from the Lilydale shales by the late Rev. A. W. Cresswell. This is apparently the specimen recorded previously as *Dalmanites* sp. (3, and repeated in 6). The *Chonetes* is a typically Yeringian fossil. Besides the fossils listed above there was collected a series of circular and polygonal crinoid stem joints which constitute a typical Yeringian assemblage. Crinoid fragments are useful in stratigraphic correlations as Moore (13) has shown.

The fossils from the above locality were collected from hard, red shales, except for some of the crinoid stem joints which came from a micaceous sandstone. I suggest that this locality be named "West of Black Springs".

The three new fossil localities described occur between the Yarra Road locality and the well-known Lilydale localities. In 1911 Jutson (11) published a paper on the Warrandyte Goldfield in which he wrote "South-east from Warrandyte, the beds should become younger, until the youngest of the area would occur a little to the north of Croydon". This inference is now supported by the collection of Yeringian fossils on Yarra Road.

In 1855 Blandowski (1) recorded fossils from "Anderson's Creek, about a mile from the junction of that stream with the Yarra Yarra". He described two fossils but figured a number of others without naming them. Blandowski did not indicate what magnifications he used in figuring the fossils, but apparently they are all microfossils, for he writes, "The multitudes of very minute fossil remains . . . with a few exceptions, can be detected only by the aid of a powerful glass," and "I have discovered by a minute examination . . . the forms exhibited in the plate." A search was made recently for the stratum to which Blandowski referred. Similar rock with microfossils was found in the area described, and may be that to which Blandowski refers. However, no extensive collecting has been done yet. As far as present knowledge goes, the fauna of these beds is without stratigraphical significance. The forms are not known elsewhere in the Melbournian or Yeringian.

From grits in Anderson's Creek (precise localities not given) collected by Jutson (11) and the Geological Survey, there are specimens of a *Spirifer* having some affinities with *S. lilydalensis* Chapman.

Chapman (3) in his list of Silurian fossils records as part of the Melbournian series the following fossils from "Anderson's Creek" which were collected from fine-grained, grey shales by the Geological Survey;

Cyrtolites sp.
Holopea wellingtonensis Eth. fil.
Orthoceras sp.
Palaeoneilo victoriae Chapman.

This faunal assemblage was no doubt considered to be Melbournian largely because of the presence of *Palaeoneilo victoriae* which has been recorded hitherto only from the Melbournian series (vide 3, p. 208). However, typical specimens have been found at Hull Road, Lilydale and Ruddock's Quarry. *Palaeoneilo* cf. *victoriae* has been collected from the Yeringian of the Kinglake district by Mr. R. B. Withers. Also, it has been recorded from Fraser's Creek and Broadhurst's Creek, both of which localities the author regards as Yeringian. The trilobite constituents of both these localities are definitely Yeringian. *Chonetes melbournensis* has been recorded from Broadhurst's Creek (3) but the specimen is not referable to that species. All the fossils from both localities are either exclusively Yeringian or common to both the Melbournian and Yeringian.

Holopea wellingtonensis, the other specific determination from "Anderson's Creek" is not found in any definitely Melbournian locality, but is recorded from Broadhurst's Creek. The species was described originally from Wellington Caves, N.S.W.

So it appears that the fossil assemblage from "Anderson's Creek" is quite indecisive. Further, the assemblage cannot be used as a stratigraphic guide because of uncertainty as to its origin. Although the fossils are marked "Anderson's Creek" they also bear the Geological Survey locality mark "B 22" which is "Watson's Creek, 2 miles below Wilson's Station". Because of the uncertainty of its location and the indecisiveness of its character, the fauna of the "Anderson's Creek" locality is of little value for the present purpose.

It has been noted that the most westerly Yeringian locality from Lilydale is Yarra Road. The most easterly Melbournian locality from Melbourne is that recorded by Chapman (3) as "Balwyn, near Templestowe" (note typographical error in punctuation). This locality, Mr. Chapman informs me, is a road cutting on the Bulleen Road on the north bank of the Koonung Koonung Creek. From this locality Mr. Chapman collected in 1905 the characteristic Melbournian fossil *Chonetes melbournensis*. Structurally, this locality is on the western limb of the Templestowe anticline.

There, unfortunately, the problem of the Melbournian-Yeringian boundary rests at present. The purpose of this paper is to bring the discussion up-to-date and to arouse interest in the problem. The area between Templestowe and Yarra Road is being searched for fossils, and the structure carefully mapped.

The Extension along Strike of the Type Yeringian Beds.

An accompanying problem to that of the westerly extension of the Yeringian beds, is the extent of their occurrence on the strike-line north and south of the type area. The average strike of the beds is about North 20 degrees East. It has often been

commented that the strata at Lilydale are very fossiliferous, yet north and south of that area the rocks seemed to be devoid of organic remains. A recent survey has revealed the presence of typical, and in some cases plentiful, Yeringian fossils along the strike both north and south of the familiar Lilydale beds.

A. North of the Lilydale Area.

(1) In a road cutting (marked on the Military Map) at the top of a high hill in Edward Road nearly $1\frac{1}{2}$ miles north of Ruddock's Quarry, the following have been collected:

Chonetes, sp. nov. (a form very common at Ruddock's Quarry).
Palaeoneilo sp.
Platyceras sp.

I suggest that this locality be termed "Edward Road Hill". This, as well as some of the other new localities, has been only cursorily examined so far, and may yield a fuller assemblage of fossils when more thoroughly investigated.

(2) In the property called "Devon Park" at the northern extremity of Edward Road, two fossiliferous localities have been found on the slopes which are part of the ancient south bank of the River Yarra. The first is at a small cut in the hillside on a track running west from the homestead to the River Yarra. The matrix is of grey shales such as are found at Ruddock's Quarry. A brief examination of the beds yielded:

Chonetes, sp. nov. (the form common at Ruddock's Quarry).
Orthoceras sp.
Phacops sp.

I suggest that this locality be known as "'Devon Park' West".

(3) The second locality in "Devon Park" is half a mile north of the terminus of Edward Road and almost in line with it, i.e. between the homestead and the downstream end of the Yering Gorge. From this place there have been obtained:

Anoplia, sp. nov.
Atrypa reticularis (Linnaeus).
Chonetes bipartita Chapman.
Dalmanella elegantula (Dalman).
D. testudinaria (Dalman).
Leptaena rhomboidalis (Wilckens).
Orbiculoidea cf. *selwyni* Chapman.
Rhynchotreta sp.
Spirifer sp.
Stropheodonta alata Chapman.
Strophonella euglyphoides Chapman.
Palaeoneilo sp.
Beyrichia sp.
Lindstroemia yeringae Chapman.

I suggest that this locality be known as "'Devon Park' North".

(4) A solitary fossil was chipped out of grey shales at the upstream end of the Yering Gorge, viz. *Chonetes bipartita* Chapman—a characteristically Yeringian form.

B. South of the Lilydale Area.

Apart from new fossil localities near Lilydale itself the following new collecting places are to be noted to the south:

(1) On Hull Road just north of where it passes under the Mooroolbark-Lilydale railway line, on the west side of the road in the gutter were found:

Strophonella euglyphoides Chapman (a typical Yeringian fossil).
Orthis sp.

I suggest that this locality be known as "Hull Road Railway Bridge".

(2) At Mooroolbark, on Hull Road, a mile south of the last-mentioned locality, in a cutting on the east side of the road north of the turn-off to Mooroolbark railway station (Military Map reference 347, 403), a particularly rich fossiliferous Yeringian series has been discovered. From these brownish shales the following forms have been recognized:

Anoplia, sp. nov.
Atrypa reticularis (Linnaeus).
Beyrichia sp.
Camarotoechia sp.
Chonetes aff. *cresswelli* Chapman.
C. robusta Chapman.
Conularia sowerbyi Defrance.
Cypricardinia aff. *contexta* Barrande.
Dalmanella elegantula (Dalman).
Fenestella margaritifera Chapman.
Goldius cf. *enormis* (Eth. fil.).
Goniophora australis Chapman.
Leptaena rhomboidalis (Wilckens).
Lindstroemia ampla Chapman.
L. yeringae Chapman.
Loxonema aff. *sinuosa* Sowerby.
Nucleospira australis McCoy.
Nuculites sp.
Orthis spp.
Palaeoneilo sp.
Pentamerus sp.
Rhipidomella sp.
Rhynchotreta sp.
Schizophoria sp.
Spirifer lilydalensis Chapman.
Spirifer sp.
Stropheodonta, sp. nov. (?)
Strophonella euglyphoides Chapman.
Strophonella, sp. nov. (?)

I suggest that this locality be called "Hull Road, Mooroolbark".

(3) At Croydon on the Ipswich Road on the rise a little east of Dorset Road, fossils were found in brownish shales in the gutter on the north side of the road, viz.:

Odontopleura rattei Eth. and Mitch.

Orthis sp.

Keilorites sp.

(4) The furthest south Yeringian locality on the strike of the Lilydale beds so far described is that at Kilsyth (2). However, a new locality was discovered recently by Dr. I. Cookson and the author at the corner of Wellington Road and Stud Road, four miles north of Dandenong. Dark, reddish shales outcrop in a cutting on the north-east corner of the crossing, and from these a number of not too well preserved fossils were collected. They include:

Chonetes bipartita Chapman.

Dalmanella elegantula (Dalman).

Both of these forms are characteristic of the Yeringian series. I suggest that this locality be known as "Rowville", the name of the place as shown on the Military Map.

Yeringian Fossil Localities.

Not a little confusion concerning Yeringian fossil localities has resulted from the fact that the actual sites have not been recorded on a map. In order to overcome this disability a map (fig 1.) accompanies this paper and the sites are numbered according to the list given below. Further, the use of more than one place-name for the same locality has often proved misleading. To overcome this further difficulty the accompanying notes have been compiled:

1. "Mooroolbark Road", "Kinsella's Gate", and "Hull Road" all refer to the red shales west of Cave Hill, outcropping in a road cutting 14 chains from the Melbourne-Lilydale highway. The road proceeds south from this highway at a point half a mile west of the township of Lilydale, and goes to Mooroolbark and thence to Croydon. The correct name for the road is Hull Road and I therefore propose that "Hull Road, Lilydale" be accepted exclusively as the locality name.

2. "Wilson's", as Cresswell has explained (5), is "On the old Melbourne Road, near the top of the hill, about half a mile above Lilydale." The fossils were collected "in the stuff thrown out of a sinking for a tank at Mr. Wilson's." This locality does not now exist, but on the same piece of road, called Albert Hill

Road by the residents, similar fossils have been collected from small outcrops and excavations. This locality and (1) have also been referred to simply as "Lilydale mudstone".

3. "North of Lilydale", "Hughes' Quarry" and "Yering" refer to the same place—a quarry at the summit of a low hill situated near the middle of the block of land bounded by the northern end of Edward Road, and the road which runs east to Coldstream, and Victoria Road. This section appears under the name of "James Shanley" on the Parish Plan of Yering. It has been said that "Hughes' Quarry" is the same as "Ruddock's Quarry" but this is not so because:

(*a*) The fossils so recorded are in a different matrix from the Ruddock's Quarry fossils.

(*b*) The following directions given by Cresswell (5) cannot be made to fit the Ruddock's Quarry locality—"About three miles to the north of the last mentioned point (Wilson's), and about fifteen chains to the west of the road that leads past the cemetery (N. and S. road) at an old quarry, known as Hughes' Quarry."

The road that leads past the cemetery is Victoria Road. I suggest that this locality be referred to exclusively by the original name of "Hughes' Quarry".

4. "Section XII. Parish of Yering", "Yering near Coldstream", "West of Yering Railway Station", "West of Coldstream Railway Station", "Yarra Flats, Yering", and "Mic. Black's Quarry, Coldstream" apparently all refer to the same locality, viz. an old quarry in a cutting (marked on the Military Map) on the road which proceeds east from "Devon Park" to Coldstream. The road forms the southern boundary of Section XII. of the Parish of Yering. The quarry is west of the Olinda Creek, at the edge of the river flats. The Geological Survey collected fossils from this place many years ago and labelled them "Sect. XII. Par. of Yering". The late Mr. Geo. Sweet collected a good deal of material from this locality, and the specimens are now housed in the National Museum. All the locality names mentioned, except the last, are hopelessly inadequate for present purposes. The last is liable to confusion with Mr. W. Black's quarry on the edge of the Toscanite on the other side of Coldstream. Until recently, when purchased by Mr. M. Black, the piece of ground in question belonged to the property called "Flowerfield" (see Military Map). I suggest that the locality be called "'Flowerfield' Quarry".

5. Fossiliferous strata outcrop at the southern end of the cutting at the northern end of which "Flowerfield" Quarry is situated. I suggest that this locality be called "'Flowerfield' Cutting".

6. "Cave Hill" limestone quarry.

7. "Melbourne Hill, Lilydale". This locality is a cutting on the main Melbourne-Lilydale road immediately west of the latter township. It is under the edge of the Older Basalt residual on the hill locally called "The Melbourne Hill". The beds outcrop beside the entrance to a quarry in the basalt and downhill for some distance. The strata comprise yellow and brownish shales.

8. "Cave Hill South" is the locality name suggested for the outcrop of limestone on the strike of the Cave Hill beds in the railway cutting a quarter of a mile south of Cave Hill (14). It is situated on the west side of the line 22 miles 11 chains from Melbourne.

9. "Mitchell's Paddock" is in the large paddock owned by the Mitchell Estate, bounded on its western and northern limits by Hull Road and the Melbourne-Lilydale highway respectively. At this point there is an outcrop of highly fossiliferous grey shales extending on and off for a chain in the banks of a rivulet which runs only in the winter. The outcrop may be located by following the fence beside the highway for 10 chains 89 links from Hull Road to a corner post then proceeding 4¼ chains south.

10. "Albert Hill Road North" is practically at the northern limit of that road on the corner of an unnamed street on the west side of the road. Numerous fossils were collected from grey shales thrown up from a telegraph pole excavation.

11. "Albert Hill Road" is a locality about the middle of the road at the corner of another unnamed street south of that mentioned in (10). A trench dug on the west side of the road revealed highly fossiliferous grey shales. Fossils were also collected from the gutter on the east side of the road.

12. "Hull Road Railway Bridge". This locality is described in section IIB (1) of this paper.

13. "Hull Road, Mooroolbark". Described in section IIIB (2).

14. "Ipswich Road, Croydon". See section IIIB (3).

15. "Rowville". See section IIIB (4).

16. "Manchester Road". See section II. (2).

17. "Black Springs". See section II. (1).

18. "West of Black Springs". See section II. (3).

19. "Yarra Road". See section II.

20. "Ruddock's Quarry", North-west of Lilydale, is on the west side of Edward Road a little north of where it is joined by the road which proceeds west from the Lilydale cemetery. It is a disused quarry on the side of a hill a short distance from the road.

21. "Ruddock's Corner" is the name given the corner of Edward Road and the road which runs west from the Lilydale cemetery. The locality is near Ruddock's Quarry, and similar grey shales outcrop. Fossils were collected from rock dug out in the re-forming of the road and in the sinking of a hole for a telegraph pole.

22. "Edward Road Hill". See section IIIA (1).

23. "West of Lilydale Cemetery". In a cutting on the road which runs west from the Lilydale cemetery, about 10 chains from Victoria Road, brown sandstones outcrop which contain fairly numerous fossils.

24. "Victoria Road Cutting" is a cutting in Victoria Road immediately north of the cemetery. At this point brown to grey shales outcrop.

25. "'Devon Park' West". See section IIIA (2).

26. "'Devon Park' North". See section IIIA (3).

27. "Yering Gorge". See section IIIA (4).

28. "Coldstream Railway Cutting". In the long cutting just south of the Coldstream railway station at a point approximately 25 miles 51 chains from Melbourne, thinly-bedded shales outcrop containing *Styliolina.* A few brachiopods have been found in the surrounding strata.

29. "Kilsyth" is a locality recorded by Chapman (2). His description of it is "Kilsyth, about 2 miles from Croydon, on the road between the railway station and Mt. Dandenong, at a depth of about five feet from the surface." The fossils came from an excavation at the corner of Ipswich and Liverpool Roads.

Note.—The Military Maps referred to are the 1935 editions of Ringwood and Yan Yean.

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Art XII.—*The Physiography of the Gisborne Highands.*

By W. CRAWFORD.

[Read 14th September, 1939; issued separately 1st July, 1940.]

Contents.

Introduction.

In this paper the writer accepts the view, which he believes to be in accord with that of most physiographers, that in Australia during Tertiary times at least, one long erosion period occurred, in which much of the continent, including the area here dealt with, was reduced to a state of mature erosion or of peneplanation. An attempt is here made to trace the physiographic history of the area from this early erosion period, or if there was more than one, from the latest erosion period to the present day. The contoured maps of the Military Survey have been used for fixing altitude in part of the area. Elsewhere heights were measured differentially by aneroid, and are therefore only approximate. In some cases a sight level was used.

The names adopted are chiefly those in local use. One Mile Creek and Fisher's Creek are names used in the early days of settlement. Unnamed features which it has been necessary to refer to have, in most cases, been given the name of an adjoining landholder, as Hassed's Creek. Jackson's Creek is the name adopted by the Country Roads Board for the main stream of the district, which on the Quarter Sheet is called the Macedon or Saltwater River. Of this creek, the West Macedon branch, which comes from the north, is regarded as the main stream; the western branch is the Slate Quarry Creek. Hassed's Creek is a smaller tributary which runs parallel to the Bacchus Marsh road. The Newer Volcanic lavas are here referred to collectively as basalt.

EXTENT AND GENERAL DESCRIPTION OF THE AREA.

The area dealt with extends from the line of differential movement about 8 miles south of Gisborne, named by Fenner (1918) the "Gisborne Fault," to the Main Divide of Victoria in the north, and from the Rowsley Fault in the west, to a few miles east of Gisborne, as shown in Fig. 1.

The rocks represented consist of slates, shales, quartzites and sandstones of Ordovician age, gravels and conglomerates marked Older Pliocene on the Quarter Sheet, Newer Volcanic lava flows, and Recent Alluvium. A quartz-felspar dyke outcrops east of Cockatoo Gully, and another, decomposed to a white clay, near the Slate Quarry, about 6 miles west of Gisborne. At least two east-west dykes, 3 or 4 feet in width and decomposed to a soft brown clay, are exposed in the bed of the Pyrete Creek, east of Mt. Bullengarook and Haire's Hill.

Ordovician rocks prevail in the western portion of the area. Towards the south they are deeply dissected by Goodman's and the Pyrete Creeks and their tributaries. Mt. Bullengarook, 2207 feet, and Haire's Hill are volcanic hills. From Mt. Bullengarook long tongues of lava run south towards Bacchus Marsh, and north-west towards Gisborne. Much of this western area is Crown land, at present of commercial value, chiefly for saw-milling purposes. A slate quarry was worked many years ago, and was re-opened for a time during the war of 1914-1918. Alluvial gold occurs in small amount; the richest locality seems to have been about 5 miles south of Mt. Bullengarook, at Cockatoo Gully, which has cut into the gravel underlying the basalt. The late Mr. William Thom, in a personal communication to the writer, stated that the largest nuggets found in the district weighed respectively 36 oz., 17 oz., and 12 oz. All were found southward of Mt. Bullengarook. To the east of Gisborne township is an area of rich agricultural land in which the old surface features are almost entirely obscured by the Newer Volcanic lava flows. The north peak of Mt. Gisborne, 2,105 feet, is the highest point. The northern portion of the area is drained by Jackson's Creek, and the southern portion by tributaries of the Werribee River and the Kororoit Creek.

PREVIOUS WORK.

The eastern portion of the area is included in Quarter Sheets 6 S.E. and 7 N.W., and these sheets remain the best guide to the area covered by them. However, some modifications are called for, and will be referred to as occasion arises.

Fenner (1) included the area, under the name of the "Gisborne Highlands," in his paper on the physiography of the Werribee area. He attributed the abrupt change of level between the Gisborne block and the Werribee plains to an east and west fault

which he named the "Gisborne Fault," and on the evidence of the contour maps, he pointed out the probability that the head gullies of the Djerriwarrh Creek had been captured by the Pyrete Creek.

In 1920 W. J. Harris and the writer published a paper (2) dealing chiefly with the sedimentary rocks of the Gisborne district, in which it was shown that the bedrock of the area is of Ordovician age. On the evidence of graptolites, an important fault was shown to exist at the Djerriwarrh Creek, and agreement was expressed with Dr. Fenner regarding the probability of stream capture. Dunn's Gully (see Fig. 1) was erroneously marked "Cataract Gully" on the map accompanying that paper. Cataract Gully is the gully running south from Mt. Bullengarook over the basalt.

The Bullengarook Gravels.

On Quarter Sheets 6 S.E. and 7 N.W. several small areas of gravel and conglomerate are shown between Gisborne and Little Bullengarook or, as it is usually called, Haire's Hill. These sub-basaltic gravels and conglomerates are, however, much more extensive and continuous than the Quarter Sheets indicate. Their eastern limit, as far as can be seen, is in Aitken-street, Gisborne, near the Presbytery. On the Calder Highway, about a quarter mile north of the bridge over Jackson's Creek, sub-basaltic gravel which may be an outlying portion of the old gravels occurs. The northern boundary of the gravels runs from Gisborne along Jackson's Creek and the Slate Quarry Creek, to some distance west of the slate quarry. Near the junction of the Slate Quarry Creek and Jackson's Creek, the gravel extends somewhat further north to about half a mile north-west of the junction of the creeks. The western boundary runs south from the Slate Quarry Creek towards Mt. Bullengarook. For the greater part, this boundary is not clearly defined, but at Carrol's Lane the gravels are somewhat sharply cut off, probably by the erosion of Goodman's Creek. Some prospecting has been done here in the gravel, and if we may take the vertical distance between the lowest gravel in a prospector's shaft, and the highest gravel on the lane about 150 yards away, to be the thickness of the gravel sheet, it must have been not less than 60 or 70 feet at this point.

Gravel occurs on the northern flank of Mt. Bullengarook, and surrounds Haire's Hill except perhaps on the west side. From Haire's Hill the gravel boundary runs east and north-east to Gisborne. Within a few miles of Haire's Hill tributaries of the Pyrete Creek have cut into the gravel, and on the more level ground towards Gisborne it is difficult to define the boundary between the gravels and sands and the soil derived from the Ordovician bedrock. Several outlying patches of conglomerate

occur as far south as Slocomb's Corner. The extreme dimensions of the gravel area are about 7 miles east to west by 4 miles north to south. A good section of the gravel is to be seen in a pit near Dohoney's Corner. Most of the material here is of a sandy nature, mottled red, and showing well marked current bedding. Occasional beds occur in which the pebbles and boulders range to more than 18 inches in diameter. On the roadside near the gravel pit a shaft has been sunk through gravel to bedrock, and the vertical distance from the bottom of the shaft to the top of the gravel-capped hill above the pit is between 60 and 70 feet. Throughout the gravels, except perhaps at the extreme eastern occurrence, large boulders occur intermingled with the finer material. On the road a mile north-west of Dohoney's Corner, rounded boulders nearly 2 feet long occur. West of Mt. Bullengarook some are at least 1 foot long, and at Slocomb's Corner and near Brucedale they may be 9-10 inches long. The pebbles and boulders consist of reef quartz, quartzite, sandstone, and very rarely of soft shaly material. They range from angular to completely rounded. No igneous pebbles have so far been found, and none which show any trace of glacial action.

Within about 2 miles of its northern edge the gravel has the form of a sheet, covering the bedrock entirely except where intersected by the basalt-filled valleys of old streams. At Slocomb's Corner and at Gisborne it occupies lower ground, with the bedrock rising up to 50 feet above it.

The contrast between the low, gravel-covered right banks of Jackson's and the Slate Quarry Creeks and their high, steep left banks of Ordovician rocks might suggest faulting. However, the highest gravel near Dohoney's Corner and at Mt. Bullengarook is almost equal in height to the Ordovician towards the north, and it is probable that the appearance of faulting is entirely due to erosion by these creeks. The northern edge of the gravel sheet is some 4 or 5 miles south of the main divide. About the same distance to the north of the divide, sub-basaltic gravel occurs near Woodend (5). As far as the writer is aware no gravel of similar age occurs between these points.

Source of the Gravel.

The nature and distribution of the gravel show that its source was to the north, that is in the direction of the present main divide. This implies uplift in that direction, with a change of grade at the northern edge of the gravel sheet. At the present day the heaviest floods do no more than move the existing gravel along the beds of the creeks, and deposit a little silt on some of the river flats. It seems, therefore, that in the production of the gravel, uplift was associated with torrential floods far exceeding any experienced at the present day. There seem to have been at first no definite drainage lines, but the gravel appears

to have been swept down in a sheet, or by a number of minor torrents, and spread out on reaching the lower grade, the flood water making its way eastward by Gisborne, south-west by Mt. Bullengarook, and southward by Slocomb's Corner.

The Old Erosion Surface.

As indicated, the Bullengarook Gravel sheet seems to have completely covered the bedrock over a considerable area, and since any differential movement would tend, from its inception, to produce greater surface relief, the old erosion surface in that area was not more uneven than that preserved under the comparatively thin gravel sheet.

It is reasonable to suppose that any wide level Ordovician area on the divides or elsewhere, where denudation is extremely slow, will at present show surface features resembling those of the old erosion surface. Probably the nearest approach to such an area lies immediately to the west of Gisborne, between the Bacchus Marsh and Melton roads. Even this area, with its low rounded hills and shallow, grassy gullies, is, owing to its proximity to the valley of Jackson's Creek, probably much more uneven than the more level parts of the old erosion surface.

Besides extensive level tracts, there seem to have been prominent hills and ridges rising conspicuously above the general level. On the western slope of Mt. Gisborne, bedrock occurs at a height of about 1,750 feet, which is 200 feet above that on the Melton road, less than half a mile away, and a ridge of bedrock in part covered by basalt extends north-east from that point to Gisborne. This ridge was of no great width, because towards the east no bedrock is exposed at the surface for more than 2 miles, and a bore put down on the north-west slope of Mt. Gisborne, about the 1,900 feet contour, penetrated a depth of 345 feet through basalt to bedrock. It seems clear that this ridge of bedrock existed at the time of the deposition of the Bullengarook gravel, and that it greatly influenced the drainage both at that time and later. There seems to have been high bedrock also at Mt. Bullengarook and at Red Rock. Mt. Tophet, with the broken ridge of bedrock running towards the north across the Calder Highway, was probably a prominent feature of the old surface.

The writer pictures the old erosion surface towards the end of the erosion period as consisting of wide, almost flat areas with here and there prominent hills and ridges, and at wider intervals still higher and older mountain masses such as the Macedon Ranges.

At Gisborne and at Slocomb's Corner, where outliers of gravel and conglomerate exist in valleys between low hills, some of the unevenness of surface may be due to denudation while the gravel was being laid down.

Differential Movement in the South of the Area.

Fenner attributed the abrupt change of level in the south of the area, largely on physiographic evidence, to a fault which he named the "Gisborne Fault" (1). Being unable to trace any distinct line, especially towards the west, which might with confidence be regarded as the line of a major fault, the writer prefers to refer to it as a line of differential movement.

The Age of the Movement Relative to the Main Divide.

If considerable differential movement had taken place on this line at the time of the deposition of the Bullengarook gravels, it might have been expected that similar gravels would also have formed on the lower block. The only locality where sub-basaltic water-worn gravel, which may be regarded as being on the lower block, has been noticed by the writer is near Coimadai, where there is little doubt, it has been brought down by the "Ancient Bullengarook River," and in part derived from the pre-existing gravel of Bullengarook.

Quarter Sheet 7 N.W. shows several small areas of Older Pliocene gravel, etc., near the Toolern Creek. Of these, all which lie to the north of Breakneck Hill are silicified bedrock or surface breccia. It is especially important to note that the small patch shown in the bottom of the gully close to Breakneck Hill is bedrock, and is not in the bottom of the gully but about 50 feet above.

A mile south-east of Breakneck Hill there is on the Quarter Sheet the note "Hard Crystalline Conglomerate". This rock can be traced back over a considerable area to the west of Toolern Creek, and across the Melton road. It is an extremely hard rock in which the original structure is hardly discernible. However, in places numerous small fragments of quartz and quartzite may be seen, and these are quite angular. It probably consists of material drifted or washed from the slopes, and subsequently metamorphosed by the lava, and probably resembled the "drift" which overlies the basalt near Sunbury (3). It might be thought that the wide, low-lying stretch of country where it occurs is the result of erosion. Its width, however, makes this unlikely, especially if, as is probable, the eastern branch of the Toolern Creek came into existence after the commencement of the Newer Volcanic period; and it seems more probable that it is the result of differential movement. The nature of this "Conglomerate" indicates that it was formed under climatic conditions differing from those that prevailed during the formation of the Bullengarook gravel, and similar to that of recent times, so that the differential movement is of later date than the uplift of the main divide. This conclusion is supported by the more mature erosion of the northern area in comparison with that bordering the southern edge of the Gisborne block.

Age of the Differential Movement Relative to the Newer Basalt.

The infilled valley of the old Toolern Creek was several hundred feet deep where it crossed from the higher to the lower block early in the Newer Volcanic period, and the infilling lava shows no sign of disturbance, so that the differential movement was probably complete at the commencement of the Newer Volcanic period.

Direction and Nature of the Movement.

From the Rowsley Fault the line of differential movement runs in a generally easterly direction for about 10 miles to Toolern Vale, where it turns north and apparently dies out in a few miles. While the general direction of the line of movement is as stated, considerable irregularities exist, especially near Toolern Vale. On evidence which like that obtained by Dr. Fenner is largely physiographic, it is suggested that the north and south portions of the movement, and part of the east and west portion near Toolern Vale, are due to simple faulting, but towards the west the movement is more complicated, with step faulting and monoclinal folding, the Coimadai fault being part of the main movement. The greatest elevation along the southern edge of the Gisborne block is north of Toolern Vale at Black Hills, 1,550 feet. It is noticeable that the Ordovician of the Black Hills to the east, and near Breakneck Hill to the west of the valley of the old Toolern Creek, is considerably higher than the basin of the old stream. This greater elevation suggests two interesting possibilities: a ridge of Ordovician through a low gap in which the old Toolern Creek found an outlet may have existed in the old erosion surface, or the differential uplift may have been greatest near the southern edge of the uplifted block, giving it a tilt towards the north.

The Pre-Basaltic Streams.

The grade of the pre-basaltic streams, except where they were rejuvenated by differential movement, appears for the most part to have been low. In only a few cases are their channels exposed, and even when later streams have cut through a tongue of basalt, the exact position of the old channel is often masked by hillside slipping. There is also the possibility of small earth movements having taken place since the time when the early lava flows occupied the old valleys (4) For these reasons, and in the absence of exact measurements of height, field relations have been given the most weight in attempting to trace the course of the old streams.

THE ANCIENT BULLENGAROOK RIVER.

The tongue of basalt which runs south from Mt. Bullengarook clearly occupies an old valley. A tongue of basalt also runs north-east from Mt. Bullengarook towards the West Macedon or main branch of Jackson's Creek. A narrow gap has been cut through this tongue by the Slate Quarry Creek near Waterloo Bridge, and the position of springs at the gap indicates the bottom of the old valley.

The mapping of the area near Dohoney's Corner, as shown on Quarter Sheet 6 S.W., requires modification. In the field it is sometimes difficult to distinguish volcanic from sedimentary areas, since surface drift covers the low-lying portions of both alike, and it is probable that at the time of the survey much that is now cleared and cultivated land was heavily timbered.

In the Quarter Sheet, bedrock is shown projecting north-east from Dohoney's Corner across Sections 30 and 31. This projection is really a ridge of gravel, or gravel-capped Ordovician. At Dohoney's Corner it is higher, and at the point where it is shown as ending, a few feet lower than the top of the basalt to the west, it dips a few feet but still continues as a prominent gravel ridge until it meets the Ordovician towards Jackson's Creek. If the basalt had flowed along an east-west valley, as would be inferred from the mapping on the Quarter Sheet, we might expect to find a ridge of basalt running in that direction, instead of which we find a gravel ridge running nearly north and south.

In the absence of a topographical survey of the locality, the following statement of heights obtained by aneroid and sight level is submitted: the highest point of the basalt north of Waterloo Bridge is 65 feet above its base near the bridge. The highest point of the basalt east of the gravel ridge is level with the base of the basalt near Waterloo Bridge. The lowest part of the gravel ridge is 40 feet above the top of the basalt to the east.

The gravel ridge at the time of the lava flow was doubtless higher than it is now, but probably was not quite as high throughout its entire length as the top of the basalt to the west. It seems to have branched towards the north, and in a hollow between the branches some basalt still remains. For the reasons given above, the writer believes that the infilled valley running north-east from Mt. Bullengarook was portion of the "Ancient Bullengarook River" valley, its only possible outlet being to the south. In that case the head of Jackson's Creek was one of the head-waters of that ancient river.

The base of the basalt is exposed at the head of Dunn's Gully, between Mt. Bullengarook and Haire's Hill, and a comparison was made by aneroid of its height there with the base of the basalt near Waterloo Bridge, with the result that it was found to be higher than that near the bridge by about 70 feet.

A quarter of a mile south of, and 120 feet higher than, the low basalt in Dunn's Gully, bedrock and gravel outcrop at the surface. Bedrock outcrops on the Bacchus Marsh road, west of Mt. Bullengarook. From about the same level as this outcrop, and on the northern slope of the mount, a well has been sunk 160 feet through basalt to bedrock. This still could not have been on the old river bed, which must have been further to the east, between the well and the gravel and bedrock outcrop, or directly under the mount.

On the Quarter Sheet, about a quarter of a mile north-east of Dohoney's Corner, a tongue of basalt is shown projecting south-west across Section 30. In line with this tongue and at the same level, running south-west across the Bacchus Marsh road, there is a wide, flat-bottomed depression, and about half a mile south of the corner at a low level, an outcrop of basalt of similar type to that towards the north. This outcrop has not been noted by the Survey. About a mile still further south, at what is known as "Chapman's" there is an outlier of basalt of similar type resting on gravel.

About three-quarters of a mile west of Rosslyn, Jackson's Creek has cut through a bar of basalt, exposing an old valley, the bottom of which is about 50 feet above the present level of the creek. These three points, which are in line with the tongue of basalt in Section 30, seem clearly to mark an old stream valley. A comparison of the depth of its channel with that of the old valley to the west of the gravel ridge suggests that the eastern stream was the greater. In that case obviously its source was not towards the south. It was probably an eastern branch of the Ancient Bullengarook River, with headwaters at Lawson's Creek, and the southern portion of its course occupied nearly the present position of the Pyrete Creek. The outlier of basalt at Chapman's is probably not the base but some higher remnant of a flow. Aneroid measurements failed to show any difference in height between it, the outcrop south of Dohoney's Corner, and the base of the bar of basalt at Jackson's Creek. Of these two branches of the Ancient Bullengarook River, the western may, by the accession of tributaries from that direction, have become the greater before their junction.

THE SLATE QUARRY CREEK.

This creek was evidently a tributary of the Ancient Bullengarook River, flowing for part of its course along the northern edge of the Bullengarook gravel sheet.

THE INFILLED BRUCEDALE-LITTLE SCOTLAND VALLEY.

Its relation to the neighbouring Ordovician shows that this stream trended north, a conclusion which aneroid measurements support. The bottom of the old valley at Little Scotland is only about 30 feet above the present creek level, so that this old stream could not have been a tributary of the Ancient Bullengarook River, but must have turned towards the east.

THE INFILLED VALLEY OF MURRAY'S SPUR.

The levels of the bedrock underlying the basalt show that this old valley trended south-west. It is in a direct line with the south-west portion of the Pyrete Creek, and drained the high ground near Mt. Gisborne. The base of the basalt at the south-west end of the spur is considerably lower than the lowest part of the divide between the Pyrete and Djerriwarrh Creeks, and the infilling basalt is of an early type.

THE OLD TOOLERN CREEK.

This creek drained the country to the south and south-east of Gisborne including the area where Mt. Gisborne now stands, and that now forming the basin of the Upper Djerriwarrh Creek. To the north-west of Breakneck Hill its tributaries must have trended north for about half a mile before turning east to join the main creek. That there was no outlet for them directly to the south is shown by the absence of lava tongues in that direction. Further evidence to this effect will be given later.

THE OLD BLACK HILL CREEK.

A small stream indicated by a lava tongue seems to have run south at the Black Hill road. It probably had only a small catchment area.

PRE-BASALTIC DRAINAGE TO THE EAST OF GISBORNE.

Reconstruction of the pre-basaltic drainage in the area to the east of Gisborne is difficult, owing to the basalt covering. If, as is probable, the drainage from the Macedon Ranges took approximately the course of the present Riddell's Creek, there would have been only a small catchment area for any streams immediately to the east of Gisborne.

An interesting problem presents itself at Red Rock Hill. To the south-east of the hill, bedrock outcrops at a height of 1,500 feet. On the southern flank of the hill, about a quarter of a mile

north-west of this outcrop and from about the same surface level, a bore was put down which passed through 359 feet of basalt to bedrock, so that the height of the old surface at the bottom of the bore is 1,141 feet. Somewhat less than three-quarters of a mile west of the bore, bedrock is exposed in a creek at a height of 1,400 feet. An extensive area of bedrock occurs to the north and north-west of the hill, so that the outlet from the low ground could not have been in either of these directions. Neither could it have been to the south-east or directly to the south. An outlet may have existed to the south-west, in the direction of the Calder Highway, but this is doubtful, since the bedrock outcrops not far to the east of the Highway and also to the west of the Highway, about half a mile south of Deverall's Hill at a height of about 1,400 feet. A possible direction is to the north-east, when it may have turned south towards Mt. Tophet, or have continued north-east towards Clarkefield. It seems most probable that in pre-Newer Volcanic times a stream trending east occupied a position not far from the present Jackson's Creek, but somewhat further north, united somewhere east of Clarkefield with a stream coming from the direction of Lancefield, and that with the exception of the reversal and diversion of portions of the Ancient Bullengarook River, the chief drainage lines did not differ greatly in position and direction from those of the present day.

Lakes of the Newer Basalt Period.

Evidence of the existence of lakes during the Newer Volcanic Period is to be found in the south of the area at the Djerriwarrh Creek and south of Couangalt.

A bed of a material, which has been determined by Dr. A. B. Edwards to be impure diatomaceous earth, is exposed in the gorges of the Djerriwarrh Creek and some of its eastern tributaries, interbedded with the lava flows. Owing to the basalt cover, the extent of the deposit cannot be seen, but it appears to be about half a mile in length and breadth, and several feet thick. The surface of the underlying lava slopes towards the south, and the diatomaceous bed indicates the former existence of a lake on the sloping surface. There being no outlet for the overflow from the lake across the high bedrock to the south, it probably made its way eastward along the edge of the lava to the Toolern Creek. Diatomaceous earth altered by the basalt is also exposed near the bottom of the Toolern Creek valley, about a mile south of Couangalt. At this locality there is evidence that the old valley was blocked by an early point of eruption in the valley itself. A few blocks of altered diatomaceous earth also occur in another branch of the creek, about half a mile to the west.

The Existing Streams.

Excluding a few of the minor tributaries, it is probable that all of the present streams which flow over Ordovician rocks, and which have not been influenced by the basalt, are of pre-Newer Volcanic age, while all that are associated with the basalt had their origin during the Newer Volcanic period. These Newer Volcanic streams may vary considerably in age, and some may vary in age in different parts of their course. Hassed's Creek probably came into existence soon after the commencement, and the upper portion of One Mile Creek near the close, of the volcanic period.

The Pyrete Creek has its source between Haire's Hill and Dohoney's Corner. It runs in a southerly direction for about 4 miles, and then turns sharply to the south-west, crossing the strike of the Ordovician rocks in a zig-zag fashion for more than 4 miles before turning south again on reaching the Bullengarook lava tongue. It probably follows very nearly the course of a branch of the Ancient Bullengarook River. The Slate Quarry Creek was probably a tributary of the Ancient Bullengarook River, flowing for part of its course along the northern edge of the Bullengarook gravel sheet. Goodman's Creek and Dunn's Gully, with the Lower Pyrete Creek, are laterals to the Bullengarook lava tongue. Hassed's Creek is portion of the Ancient Bullengarook River reversed by the lava flows.

Jackson's Creek.—Evidence has been brought forward that the western portion of this creek was part of the Ancient Bullengarook River, diverted to an easterly course by the Bullengarook lavas. Further east its course was determined by lava flows from points of eruption to the north and the south. Toolern Creek propably occupies nearly the position of the pre-basaltic stream, but with considerably less catchment. Where it crosses the "Gisborne Fault," from the higher to the lower block, it is not lateral to but runs for about a mile along the centre of the narrow tongue of lava. This is probably due to the formation of a depression in the lava by the draining away of the central, more plastic portion. The Eastern Branch of the Toolern Creek commences as a lateral to the lava. The gullies near Breakneck Hill are probably about the same age as the Eastern Branch of the Toolern Creek.

The *Djerriwarrh Creek.*—The lake which existed in the Djerriwarrh area ultimately found an outlet to the south, either by tapping by a gully on the Ordovician, or by the raising of its level by a later lava flow. Once the outlet was formed, rapid downward cutting through the soft diatomaceous bed and the

Ordovician gave rise to the deep gorge of the Djerriwarrh Creek, which runs for nearly a mile parallel to, and about a quarter of a mile distant from, the western edge of the basalt.

The Points of Eruption and the Lava Flows.

Mt. Bullengarook and Haire's Hill.

The earliest flow from these centres appears to have taken a north-easterly direction along a branch of the Ancient Bullengarook River. The depth—upwards of 400 feet—of the gullies lateral to the lava flow south of Mt. Bullengarook, suggests that it is of an early date. However, Cataract Gully, on the basalt, is, except near its mouth, an insignificant depression which is crossed by a road without even a culvert being necessary, and is quite comparable with streams of similar catchment near Mt. Gisborne and on the Keilor Plains.

At Mt. Gisborne the commencement of activity seems to have taken place towards the northern flank of the present hill. Later, about the middle of the volcanic period, a rounded hill which sent out lava flows in all directions, except to the north-west where high bedrock was in the way, was built up, forming the central portion of the present mount. A series of eruptions then built up the north peak, and lastly the south peak was formed. Many other points of eruption, which need not be described here, exist in the area.

Stream Capture.

The writer formerly shared the opinion that the Upper Pyrete was at one time a head gully of the Djerriwarrh Creek, and was captured by a tributary of the Ancient Bullengarook River. He has since abandoned this view for the following reasons:—

Early in the Newer Volcanic Period the south-west reach of the Pyrete Creek was already entrenched in a valley which was far below the level of the divide between the Pyrete and Djerriwarrh Creeks. The evidence for this is the unfilled valley of Murray's Spur, which must have continued in a south-west direction. Evidence has been given which suggests that in pre-volcanic times the Upper Pyrete had a much greater catchment area than the present creek has, and it is unlikely that such a stream, if early in its history it flowed south towards the Djerriwarrh Creek in line with the strike of the Ordovician rocks, would not maintain its course, or that it would be captured by a tributary of an equal stream some miles to the west. It seems more probable that the south-west reach of the Pyrete is due to the configuration of the old erosion surface, and that the creek has occupied very nearly its present position since its commencement.

The River Flats of Jackson's Creek.

Along Jackson's Creek, wherever bedrock is exposed above a bar of basalt, a flat has been formed. The most important of these flats is that at Gisborne, its greatest width being about half a mile, and its length a mile and a half. A large flat exists at Rosslyn, above the bar at Little Scotland, which has been completely cut through, so that the Rosslyn flat is continuous with that at Gibsorne. The size of the flats at Gisborne and Rosslyn is probably due, not so much to the comparatively narrow bars of basalt which have been the direct cause of their formation, as to the wide stretch of basalt which the creek enters upon about half a mile east of Gisborne, and which has prevented the creek from reaching a sufficiently low level to breach the bars by undercutting. Waterloo Flat formed while the Slate Quarry Creek was cutting through the bar of basalt near Waterloo Bridge. This bar is now completely cut through. About a mile west of Rosslyn the remnant of a small terrace exists about 50 feet above creek level. This was probably a flat formed while the creek was cutting through the bar of basalt which it crossed at that point. To the east of the mouth of One Mile Creek a flat, several acres in extent, occurs in volcanic rock. The light scoriaceous nature of the rock, and the presence of beds of unconsolidated volcanic material, indicate that this was probably a point of eruption.

Some General Remarks.

It is difficult to decide when the evolution of the present topography began. It probably had its beginning long prior to the end of the last great erosion period. The Macedon Ranges, which lie to the north-east of the area particularly dealt with, have existed for a very long time as a prominent mountain mass. The course of a pre-basaltic stream was approximately that of the present Riddell's Creek (5). At that time this was probably the most important stream in the eastern area, and its basin seems to have extended in width approximately to a line from Gisborne to Sunbury. Acting, as it may have done, through a very long period of time, it would have an important effect in the development of the pre-basaltic topography.

The bedrock, which here and there rises above the basalt between Gisborne and Sunbury and between Mt. Tophet and Clarkefield, consists almost wholly of the hard sandstones and quartzites and the hardened shale beds of the "Riddell Grits" (2), and it is probable that these high areas of bedrock are due to their resistance to erosion and not to the Tertiary earth movements which affected the western portion of the Gisborne district.

No drift wood or fossils of any kind have been noticed in the Bullengarook gravels. It is probable that climatic conditions played an all-important part in their formation, and it is possible that the elevation of the main divide may have preceded the formation of the gravels by a long period. If this period had been greatly prolonged, however, there should be more distinct evidence of the existence of well-developed drainage lines in the area at the time of formation of the gravels.

If recent earth movements of appreciable magnitude have occurred, there should be rejuvenation of the streams and consequent rapid erosion in the areas affected. In the Gisborne flat, where beds of clay, sand, and gravel containing basalt pebbles occur, much work is being done by Jackson's Creek, by side-swinging, with but slight lowering of its bed. The same creek near Rosslyn has worn a particularly deep and steep-sided channel, which may be accounted for by the cuttng through of the bar of basalt at Little Scotland.

In places along some of the tributaries of the Pyrete and Djerriwarrh Creeks, a great deal of material has been removed quite recently. This material consisted chiefly of soil and fragments of rock from the hillsides, which had accumulated in the gully, so that the work done represents the widening rather than the deepening of the valley.

Toolern Creek, on its passage from the higher to the lower block, has worn a deep channel with projecting points of basalt with vertical walls and many fallen blocks. Above these points there are usually small flats at creek level, the occurrence of which on such a small stream shows that downward cutting has been slow and probably normal under existing conditions of grade and rock structure.

The most striking case of rapid erosion occurs near the mouth of Cataract Gully, where there are vertical columns of basalt 60 or 70 feet high, and the creek bed is littered with fallen blocks. This is doubtless due to the creek having reached the underlying gravel beds of the old Bullengarook River, and it seems probable that in the area dealt with, no appreciable earth movements have occurred since the commencement of the Newer Volcanic Period, and that the forces now acting are those of erosion only.

This statement is not intended to apply to the Coimadai area, which has not been closely examined. The writer has long suspected that the Coimadai limestone was derived from the Mt. Bullengarook lava, being led to that opinion by the abundant

calcium carbonate in the cavities and associated with the basalt south of Mt. Bullengarook. The existence of the limestone basin adjacent to the lava stream is more difficult to account for.

Summary.

Gravels, referred to here as the Bullengarook gravels, cover a much more extensive area in the Gisborne Highlands than is suggested by the Quarter Sheets of the Geological Survey. The extreme dimensions of the gravel area are about 7 miles east to west, and 4 miles north to south, with a thickness of from 60 to 80 feet. The pebbles and boulders are unsorted and up to 2 feet in diameter. They range from angular to completely rounded, and consist essentially of reef quartz, quartzite, and sandstone. They occur in the form of a sheet, covering the bedrock except where intersected by the lava-filled valleys of old streams. The gravel came from the north, indicating uplift in the direction of the Main Divide, with a change of grade at the northern edge of the gravel sheet, associated with torrential floods in excess of any experienced at the present day.

In other parts of the area the surface is composed of widespread flows of volcanic rock, younger than the gravels. The old erosion surface underlying the gravels and volcanic rocks appears to have consisted of wide, almost flat areas with prominent hills and ridges here and there, dominated by the monadnock of the Macedon Ranges to the north.

The southern limit of the Gisborne Highlands is marked by a line of differential movement, which raised it above the basalt plains to the south. This differential movement occurred subsequently to the uplift of the Main Divide, but prior to the extrusion of the volcanic rocks.

The lava flows have largely obliterated the pre-basaltic drainage system, but it seems probable that the chief drainage lines did not differ greatly in position and direction from those of the present day.

Acknowledgments.

The writer gratefully acknowledges his indebtedness to Dr. A. B. Edwards for preparing the map in a form suitable for publication, and attending to the typing of the manuscript, and for much help during the progress of the work; and to Mr. H. E. Dixon, of Gisborne, whose extensive local knowledge has made his assistance of especial value.

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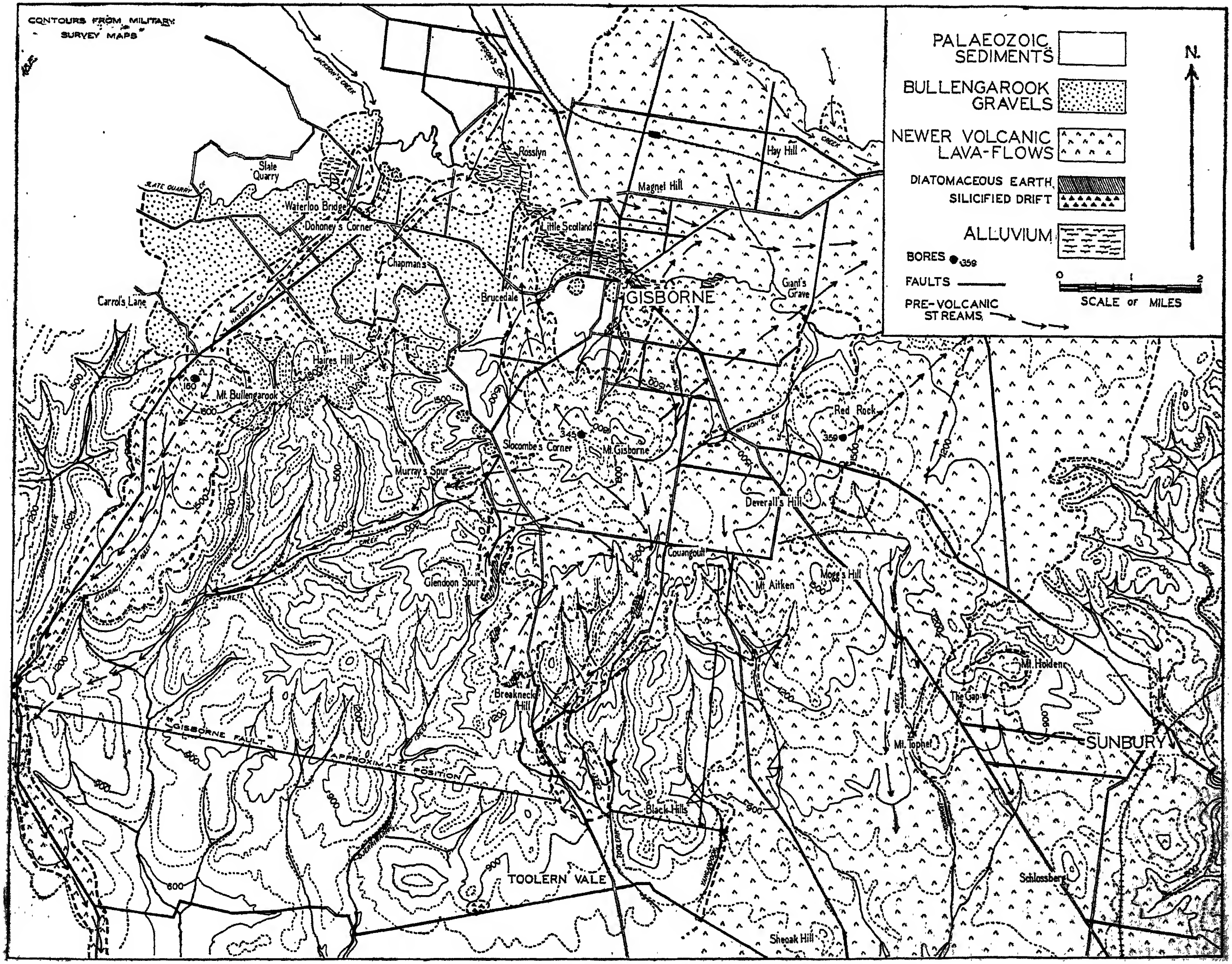

Fig. 1.—Locality Map (see Crawford's Paper).

[PROC. ROY. SOC. VICTORIA, 52 (N.S.), PT. II., 1940.]

ART. XIII.—*The Cainozoic Volcanic Rocks of the Gisborne District, Victoria.*

By A. B. EDWARDS, Ph.D., D.I.C., and W. CRAWFORD.

[Read 14th September, 1939; issued separately 1st July, 1940.]

Contents.

Introduction.

The volcanic rocks which cap much of the Gisborne Highlands (fig. 1) belong to the Cainozoic Newer Volcanic Series, and range in type from limburgite to acid-trachyandesite. The points of eruption from which the lavas issued stand up as prominent hills, of which Mt. Gisborne (2,105′) and Mt. Bullengarook (2,207′) are the two highest. The greatest variety of rock types lies within the area bounded on the north by the Melbourne-Bendigo railway line, on the west by Goodman's Creek, on the south by the Coimadai-Toolern Vale road, and on the east by the Black Hills road. This area has been mapped in detail (fig. 2), mainly by Mr. W. Crawford, of Gisborne. The laboratory study and chemical analyses were made by Dr. Edwards at the Geology Department, University of Melbourne, by the kind permission of Professor Skeats.

General Geology.

THE VOLCANIC HILLS.

The eroded volcanic hills of the Gisborne Highlands appear at their most striking when viewed across "The Gap" from Schlossberg Hill, on the north side of Mt. Alexander Road (Calder Highway) about two and a half miles north-west of Digger's Rest township. Similar volcanic hills, Mt. Kororoit and

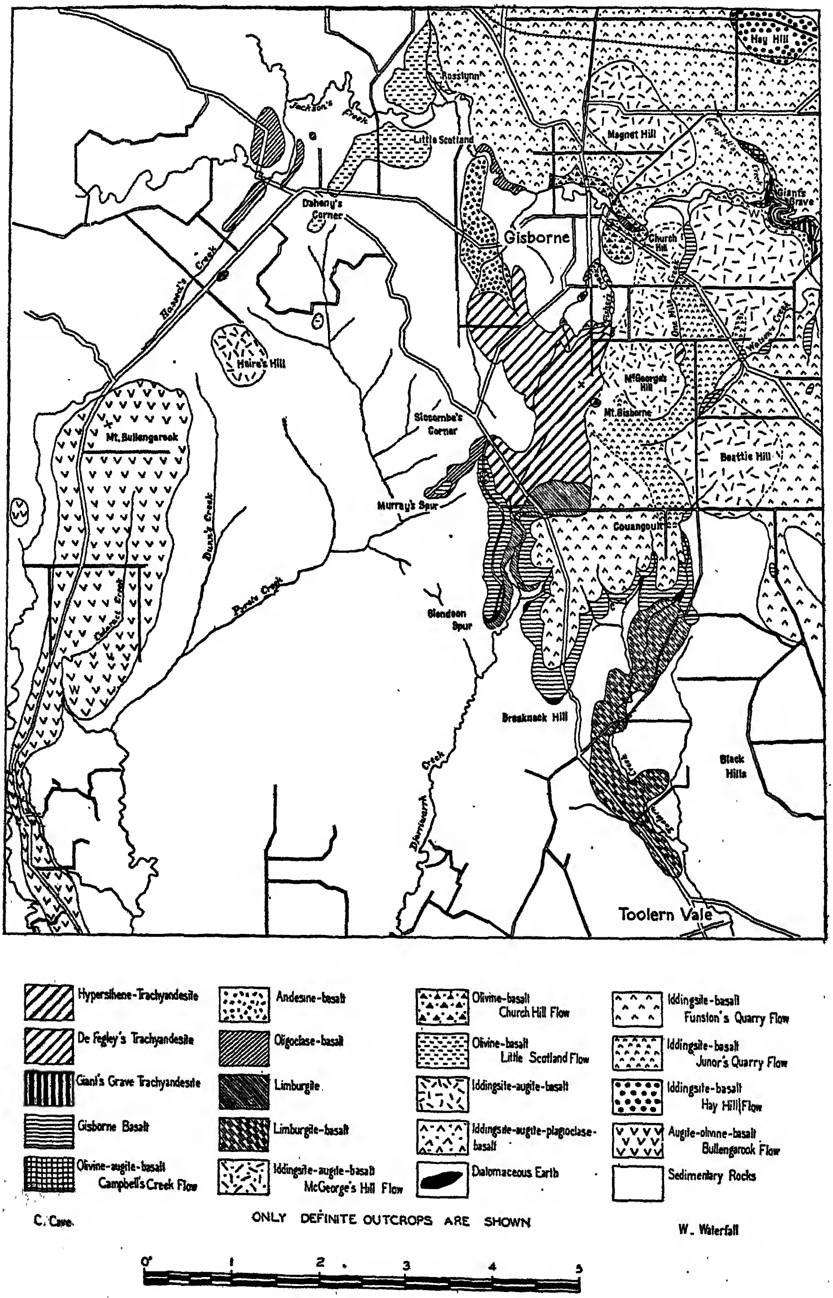

Fig. 2.—Geological Map of the Gisborne District, showing the distribution of the Newer Volcanic rocks.

Sheoak Hill, stand up to the south-west of this vantage point, on the northern margin of the low-level basalt plains abutting the Gisborne Highlands.

Several of these hills, namely Red Rock, Mogg's Hill, Deverall's Hill, O'Brien's Hill, and Mt. Holden, present closely comparable profiles—a more or less flat top surrounded by rocky cliffs on all sides but one, where there is an easy slope down to the surrounding plain. The sides of this sloping tract are also marked by rocky walls in their upper parts. These profiles arise from the fact that erosion of the scoriaceous material of the original cone has exposed the central plug of the volcano and the sides of the lava flow which breached the cone (fig. 3). The lavas that issued from these vents were among the latest extrusions of the district, and gave rise to a generally similar type of porphyritic iddingsite-augite-labradorite-basalt.

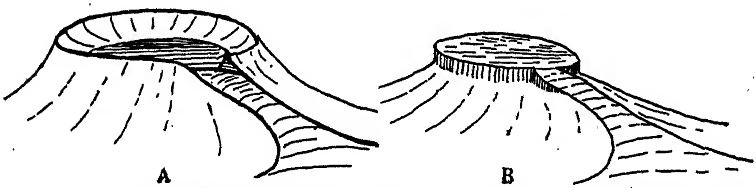

FIG. 3.—Illustrating the origin of the flat-topped volcanic hills in the Gisborne District. A. The breached volcanic cone. B. After erosion.

Mt. Gisborne.

Is the most westerly as well as the highest of the group of volcanic hills near Gisborne township and differs from the others both in appearance and structure. It consists of two peaks, the northerly one rising to 2,105 feet above sea level, and the southern one to just over 2,000 feet, with a saddle about 600 yards long connecting them. A third peak, McGeorge's Hill (1,900′) occurs on the north-eastern slope of the north peak, but really belongs to the group of flat-topped hills already described.

Mt. Gisborne is built up of a series of lava flows ranging in composition from limburgite to acid trachyandesite, with olivine-basalts predominating, and is the most complex Tertiary volcanic hill yet known in Victoria. It also appears to be the earliest centre of eruption in the Gisborne district, since its later flows are closely comparable with the flows from the adjacent cones. The volcanic activity appears to have commenced with the extrusion of flows of oligoclase-basalt, andesine-basalt, and limburgite. The andesine-basalt issued from near the northern flank of the present mount; the oligoclase-basalt flowed out to the west, filling a valley now represented by Murray's Spur; and the limburgite flowed southwards into a valley now represented by Glendon Spur. The vents from which these flows issued

are hidden beneath later lava flows, and there is no evidence as to their order of extrusion. An extensive flow of limburgite-basalt occurred in the valley of the pre-basaltic Toolern Creek, and flowed down that valley towards Toolern Vale. The vent of this flow appears to have built up to a sufficient height to effectively dam the valley, and prevent any later extrusions from flowing down it. At about this time, also, the olivine-basalt of Church Hill, to the north of Mt. Gisborne, was extruded (probably from a vent near Magnet Hill, judging from its surface slope).

A period of quiescence followed these eruptions. Extensive deposits of impure diatomaceous earth, suggestive of temporary lake conditions, overlie the limburgite and limburgite-basalt flows (5).

The next extrusions are mostly characterized by the presence in varying amounts of partially resorbed hypersthene, labradorite, and anorthoclase. The most extensive are flows of olivine-basalt (the Gisborne Type). These directly overlie the diatomaceous earths, the oligoclase-basalt, limburgite, and limburgite-basalt, on the western and southern flanks of the mountain, and extend as far south as the higher Ordovician ground of the Breakneck and the Black Hills. On the east and north-east it is exposed beneath later basalts in several "windows" in creek beds, and along One Mile Creek in the vicinity of its junction with Jackson's Creek.

The Gisborne basalt was followed by the extrusion of a sheet of iddingsite-basalt (the Funston's Quarry flow), which extended as far south as the Ordovician hills, and also appears in the bed of Fisher's Creek, south of the township of Gisborne, and on the road leading from Gisborne to Mt. Gisborne, north-west of Section VII.

At least three flows of trachyandesite developed at this time. A glassy, basic trachyandesite (De Fegley's Flow) issued to the north-west, partially covering the earlier andesine-basalt flow down the pre-basaltic Carnegie's Creek. This in turn was partly covered by an acid, grey trachyandesite which also flowed out to the south-west, covering limburgite, Gisborne-basalt, and oligoclase-basalt, and to the north-east. Its full exent in this direction is hidden by later flows, but it is revealed in a "window" in One Mile Creek beneath the flow from McGeorge's Hill. A third trachyandesite, which outcrops as the third lowest of the four flows exposed in Jackson's Creek in the vicinity of the Giant's Grave, also probably came from Mt. Gisborne. Xenoliths in the trachyandesite suggest that a flow of hypersthene-basalt, now completely hidden, also occurred during this stage.

These were followed by an extrusion of iddingsite-augite-basalt from a new vent, McGeorge's Hill, on the north-eastern flank of the north peak of Mt. Gisborne. This stage seems to have coincided with a period of general activity throughout the

district, when the various volcanic cones mentioned were formed. A generally similar type of lava issued from them all. Then a final extrusion from near the south peak gave rise to the Junor's Quarry flow of iddingsite-basalt (Ballan Type) on the eastern side of the mountain. This forked, going partly to the south-east and partly to the north-east, between and covering the porphyritic flows from McGeorge's Hill and Beattie Hill, as far as the Mt. Alexander Road.

Magnet Hill.

North of Gisborne and east of New Gisborne, is an oval-shaped hill of rather glassy porphyritic iddingsite-augite-basalt, more or less comparable with the McGeorge's Hill flow. It is probable that several flows issued from this vicinity. Only so can one explain the occurrence of an area of oligoclase-basalt to the south of Magnet Hill, in Jackson's Creek, and the olivine-basalt (Church Hill flow) which overlies this oligoclase-basalt. Iddingsite-basalt, which overlies the Church Hill flow and underlies the Magnet Hill porphyritic flow, may also have come from this source.

Hay Hill.

In the north-east corner of the area, is a small hill of fine-grained andesitic-basalt, overlying the widespread porphyritic type of the plain. It is similar to the latest (Junor's Quarry flow) flow from Mt. Gisborne.

Haire's Hill (Little Bullengarook).

West of Gisborne and close to the north-eastern flank of Mt. Bullengarook is Haire's Hill, a dome-shaped hill of porphyritic iddingsite-basalt which is more or less isolated, although a flow appears to have issued from it to the north-west.

Mt. Bullengarook (2,207′).

Immediately to the west of Haire's Hill provides a striking contrast. It consists of a pedestal of Ordovician sediments rising to at least 1,900 feet above sea level (5), capped by about 300 feet of basalts. The earliest flow appears to have been an oligoclase-basalt which flowed to the north, along what was presumably a continuation of the pre-basaltic Bullengarook River. This early flow has undergone a certain amount of erosion, and its outcrop is not everywhere continuous. Spoil from a well shaft on the northern flank of the hill indicates that this early flow is overlain by a porphyritic iddingsite-basalt similar to that of Hair's Hill. Overlying this there is a very considerable flow of porphyritic augite-olivine-basalt which flowed out to the south, filling the valley of the pre-basaltic Bullengarook River for a distance of twelve and a half miles. It is to this lava flow that Mt. Bullengarook owes its distinctive profile. A contour plan of this flow has been given by Charles Fenner (11, p. 260). In its widest part the flow is about a mile and a half across, but about four and a

half miles downstream it narrows to almost nothing, and then widens again. There appears to be a distinct descent in level at this point, suggestive of a slight downwards movement of the block to the south. The basalt is similar on both sides of this point. Goodman's Creek and the Pyrete Creek (Dunns Creek at the northern end) have formed deep lateral streams on either side of this flow; while in the upper portions it has been deeply dissected by Cataract Creek, which starts as a slight depression on the surface of the lava, and quickly deepens into a gorge, with a waterfall where it spills over on to the Ordovician bedrock.

Lava Fields.

The form of the lava fields in the western part of the Gisborne Higlands is in striking contrast to those in the eastern part. The long narrow flow running south from Mt. Bullengarook is an excellent example of Keble's conception (14) of a "confined lava field," i.e. one in which the lava flow failed to completely fill the valley into which it flowed. The drainage flowing down such a valley is still retained between the original interfluves, but tends to reconstitute itself as a pair of lateral streams on either side of the lava field, which becomes elevated to the position of a ridge as erosion proceeds.

The lava field extending eastwards from Gisborne, on the other hand, is an example of an "extensive lava field." The earlier flows were confined within the pre-basaltic valleys, as in the western area, but repeated extrusions gave rise to such a volume of lava that the pre-basaltic topography was completely buried, except for the summits of a high ridge of Ordovician sediments trending north-east from Mt. Tophet towards Clarkefield, and the high ground to the west of Gisborne. The drainage was completely deranged, and developed as a new, sinuous stream (Jackson's Creek) consequent on the gradient of the lava plain. This stream has cut down below the surface of the plain, sometimes to the underlying bedrock, and has incised its sinuous course in the process giving rise to in-grown meanders. Where it crosses the infilled pre-basaltic valleys, as at the Giant's Grave, the extra thickness of lava flows has acted as a bar, causing the development of a narrow gorge. Where it has reached the softer bedrock the valley has widened as a result of undercutting, and flats have formed in which the stream has cut meanders.

The Giant's Grave.

This is a cut-off spur of one of the in-grown meanders. A pre-basaltic valley trending north-east existed at this point, and was infilled by a series of lava flows, of which four are exposed in section. The presence of soft or weathered rock at the base of the third flow (down) has enabled the stream to undercut the rock above this layer, until finally it breached the lava at this point, and broke through into its valley on the other arm of the in-grown

meander. With further grading of its bed the stream has abandoned the meander, and has worn down the cut-off spur until it looks like an enormous burial mound set in a walled amphitheatre.

Waterfalls.

The gorge tract continues for some distance upstream to a waterfall, which has resulted from undercutting at the junction of the second and third lava flows of this series. Another waterfall occurs on Cataract Creek (Bullengarook flow) where the stream which has its origin on the surface of the small lava plain south of Mt. Bullengarook falls over the edge of the basalt on to the Ordovician sediments. Undercutting has produced a considerable waterfall at this point, and a narrow, gorge-like valley extends for some distance upstream.

Age of the Lava Flows.

Although the lava flows of the Gisborne district have a quite youthful appearance, the amount of erosion which they have undergone is sufficient to show that they are not of Recent age. They overlie the Bullengarook gravels (5), and were extruded after the differential uplift which raised the Gisborne Highlands above the plain to the south. There is no indication of any prolonged break between the lava flows at any stage; and since the later members appear to be contemporaneous with the basalts that cover these plains, and which are regarded as of Pleistocene age (4, p. 257), they are all probably of this age.

Petrology.

The volcanic rocks of the Gisborne district fall into two main groups:—(1) those which appear to be typical differentiates of an olivine-basalt magma, and (2) those which appear to be "abnormal" differentiates, namely the hypersthene-trachyandesites, and hypersthene-bearing basalts. For convenience the "abnormal" types are grouped together in the following petrological descriptions. The nomenclature used is the same as adopted in earlier papers (8, p. 256).

A. Abnormal Differentiates.

Trachyandesites.

Three flows of trachyandesite have been discovered in the Gisborne district.

Hypersthene-trachyandesite.

This rock outcrops on the north-western and south-western flanks of Mt. Gisborne, overlying the de Fegley's trachyandesite, Gisborne basalt, limburgite, and iddingsite-basalt (Funston's Quarry flow). It also outcrops in the bed of One Mile Creek,

where it is overlain by the iddingsite-basalt, from McGeorge's Hill. It consists of phenocrysts of sanidine, anorthoclase and plagioclase felspars, and of hypersthene, augite, and occasionally olivine, set in a hyalopiltic to pilotaxitic groundmass. Rounded xenocrysts of quartz are present in every section. The sanidine phenocrysts are simply twinned or untwinned, and rounded. Their margins are generally vermiculate, owing to reaction with the enclosing magma. Sometimes this process of resolution has progressed so far that only a "brain structure" of felspar remains. Occasionally this corroded felspar shows closely-spaced but very faint lamellar twinning, suggesting that it is anorthoclase. The plagioclase, which shows strong lamellar twinning and sometimes zoning, is also corroded and frequently more or less vermiculate. The maximum extinction angle obtained in the symmetrical zone was 32°, corresponding to a composition of about Ab_{40}. These felspar phenocrysts, especially the plagioclase, tend to gather into clots, in company with crystals of hypershene and sometimes aguite. Some of the clots attain to 2 and 3 cm. in diameter, and resemble norites. They represent the preliminary stage in the formation of the norite xenoliths described below.

The hypersthene is distinctly pleochroic with X = pinkish to yellowish, Y = colourless or pale green, Z = green. It has a (—) 2V between 60° and 90°, so that it probably contains 20 to 30 per cent. of the $FeSiO_3$ molecule (En_{70}). The larger hypersthene crystals are somewhat corroded and even vermiculate, though never so much as the felspars. Small lath-like crystals of hypersthene occur in the groundmass, and are generally edged with a monoclinic pyroxene showing an extinction angle of about 40°. Occasionally the hypersthene crystals occur in small clots, free from felspar. A monoclinic pyroxene with a large extinction angle and (+) 2V greater than 45° also occurs as phenocrysts. It is presumably an augite and is not vermiculate. The pyroxene fringing the laths of hypersthene in the groundmass may be of the same composition.

Every section contains one or two rounded grains of quartz. These appear to be xenocrysts derived from assimilated sedimentary rock. They do not show any semblance of the forms usually exhibited by quartz phenocrysts in rhyolites or similar rocks. Moreover, microphenocrysts of olivine with iddingsite are occasionally present. In weathered specimens this olivine is more or less altered to serpentine. Large apatite crystals (1 mm. x 0.2 mm.) enclosing fibrous inclusions parallel to the prism axis also make an occasional appearance. The fibrous inclusions are pleochroic from brown to black. The groundmass consists of microlites or small laths of oligoclase (Ab_{75}), incipient pyroxene crystals, and dark glass.

As the analysis (Table I., No. 1) indicates, this rock is an acid trachyandesite, which closely resembles the trachyandesite flows of the Coliban district (8, p. 258) both in chemical and mineralogical composition.

de Fegley's Trachyandesite.

This is a dense, almost glassy, black rock, studded with phenocrysts of felspar that may be as large as 5 mm. across, but are generally smaller. It forms a flow on the north-western flank of Mt. Gisborne, overlying the andesine-basalt that outcrops near Brucedale, and overlain by the trachyandesite just described. In hand specimen it somewhat resembles the black trachyandesite glass of the Coliban district (8, p. 258). In thin section it is seen to consist of phenocrysts of hypersthene, augite, partially resorbed plagioclase, and occasionally sanidine, in a hyalopilitic groundmass of oligoclase microlites (Ab_{80}), granules of pyroxene and abundant glass. Most of the glass is black and opaque under low magnification, but under high magnification resolves into innumerable globules of iron ore in a colourless base. Patches of a green, glassy material which turns yellow on weathering are also present.

The hypersthene phenocrysts are faintly pleochroic from pink to green, with (—) 2V between 60° and 90° (En_{70}), and are often partially resorbed, though some retain their idiomorphic outline. They enclose crystals of apatite and sometimes enclose granules or aggregated granules of augite. There is a marked tendency for the crystals to gather into glomeroporphyritic clots. The augite has (+) 2V greater than 45°, and although sometimes embayed, never shows the vermiculate structure so common in the felspar and hypersthene phenocrysts. The smaller plagioclase phenocrysts are rounded or lens-shaped, but the larger crystals and the sanidine phenocrysts (and anorthoclase?) show "brain structure" resorbtion to a marked degree. Xenocrysts of quartz are numerous. They are rounded and often appear to have suffered slight fusion at the edges. They never possess any suggestion of crystal outline, but are generally ovoid in shape and, like those in the acid trachyandesite, are probably derived from sediments.

A chemical analysis of this rock is shown in Table I., No. 2. It reveals it as a distinctly more basic variety of trachyandesite than the adjacent flow.

Giant's Grave Trachyandesite.

A further flow of trachyandesite, closely comparable in chemical composition (Table I., No. 3) to the de Fegley's flow, is exposed in Jackson's Creek in the gorge above and below the Giant's Grave, where it forms the third flow down from the surface. It extends from the waterfall above the Grave as far downstream as Watson's Creek, and outcrops in the bed of that creek, and

also in the bed of Campbell's Creek for a short distanct upstream from its mouth. These exposures and a further one in the bed of a small creek (MacGregor's Creek) at the first bend downstream from the Giant's Grave, suggest that the bottom of the flow slopes to the north-east, in which case the lava flow came from the direction of Mount Gisborne. It overlies a flow of the Church Hill type of olivine-basalt, and is overlain by iddingsite-basalt, and iddingsite-augite-labradorite-basalt.

In microtexture also it resembles the de Fegley's flow. In the upper and lower parts of the flow the groundmass is largely glass which is practically opaque from the presence of iron-ore dust, and encloses a few highly vermiculate phenocrysts of labradorite and anorthoclase, together with an occasional crystal of aguite. In the central parts of the flow the groundmass is more crystalline, and consists of microlites of oligoclase, granules of iron ore, and greenish glass. Small microphenocrysts of pleochroic hypersthene are numerous, and occasionally have aggregated into clots along with stumpy columnar crystals of labradorite. Large phenocrysts of vermiculate labradorite and anorthoclase are not as numerous as in the chilled margins.

HYPERSTHENE-BASALT.

In the acid trachyandesite there occur numerous xenoliths, 2 to 3 cm. in diameter, of a grey, minutely vesicular rock, showing numerous growths about 1 cm. in diameter of radiating crystals suggestive of spherulitic growths. Thin sections revealed that these xenoliths consist of a hypersthene-basalt. Subsequently an ovoid xenolith of the same material, measuring 15 cm. x 10 cm. x 6 cm., was found and broken out of the trachyandesite. Further sections and an analysis were made of this rock, which is unique among Victorian basalts. Its close relation to the trachyandesites cannot be doubted.

It contains occasional phenocrysts of hypersthene and olivine. The hypersthene shows distinct pleochroism from pink to green, and has (—) 2V between 60° and 90°, so that its composition may be taken as about (En_{70}). Occasionally it occurs in clusters of several crystals. The olivine phenocrysts occur only sporadically. They are corroded and rimmed with iddingsite. The bulk of the rock is a finely vesicular intergrowth of plagioclase and lath-like prisms of colourless hypersthene (bronzite ?) which are edged with a later pyroxene that has an extinction angle of 40°, measured from the extinction position of the hypersthene, and a distinctly higher birefringence. The size of the hypersthene core in these laths is variable. Sometimes it forms only a needle inside the augite, at other times it forms the bulk of the crystal. These laths are identical, except that they are larger, with the hypersthene laths in the groundmass of the acid trachyandesite. The plagioclase occurs as short,

stumpy laths and as allotriomorphic plates intersertal to the pyroxene laths. It has a composition about Ab_{35}. Iron ore occurs as numerous rods in this base, often moulded on the laths of pyroxene; and as granules intergrown with the marginal augite, though never with the hypersthene cores.

The close affinity of this rock to the trachyandesites is brought out by the analysis (Table I., No. 4), which also reveals the relatively high proporition of ferromagnesians to felspars in the rock.

NORITE XENOLITHS.

Reference was made in an earlier paper (8, p. 294) to the occurrence of norite xenoliths both at de Fegley's quarry, Gisborne, and elsewhere. During the present study, further xenoliths of this nature have been found both in the de Fegley's trachyandesites and in the grey trachyandesite. These consist of prisms of hypersthene (about En_{70}) intergrown with laths and allotriomorphic plates of labradorite (about Ab_{35}), sometimes with accompanying augite. They are clearly derived from the aggregation of the hypersthene and plagioclase phenocrysts in the trachyandesites, and every stage in their growth can be observed.

Recently the Director of the Geological Survey (Mr. W. Baragwanath) discovered a block of such xenolithic norite, about 20 cm. x 20 cm. x 15 cm., on the dump from a shaft sunk on the Campaspe Deep Lead, near Kyneton. A selvedge of the enclosing rock still adhered to part of the block, and a thin section showed it to be the less acid of the two trachyandesites which occur in that district (8, p. 258), so that this norite block is presumably of the same origin as the smaller xenoliths found at Gisborne. This rock consisted of coarse allotriomorphic crystals of labradorite (Ab_{30}) and interlocking crystals of strongly pleochroic hypersthene (about En_{70}) and faintly violet augite, together with iron ores, and occasional large apatite crystals with black fibrous inclusions. An analysis of this rock was made (Table I., No. 5) as more or less representative of these cognate xenoliths, and, as will be seen, it differs considerably in chemical composition from any other Newer Volcanic rock on record in its high CaO content and low alkalies. In mineral and chemical composition it compares somewhat with certain highly porphyritic Japanese basalts (21).

GISBORNE BASALT.

This distinct variety of basalt occurs to the south-west, south, east, and north-east of Mt. Gisborne, and thin sections in the University collection (Nos. 3547, 3558) indicate that a similar rock occurs north-east of the area near Riddell. At Murray's Spur the Gisborne basalt overlies oligoclase-basalt; at Glendoon Spur and south of Mt. Gisborne it overlies limburgite and

limburgite-basalt, and at the mouth of One Mile Creek it overlies olivine-basalts of the Church Hill type. It is overlain in its turn by the acid trachyandesite on the south-west of Mt. Gisborne, and by a variety of iddingsite-basalt flows. The Gisborne basalt was almost certainly extruded as several flows, which have minor differences but a strong general resemblance.

In hand specimen it is a dark greenish-grey rock, showing phenocrysts of felspar up to 5 mm. in diameter, with fewer and smaller phenocrysts of pyroxene and olivine. The phenocrysts consist of anorthoclase and labradorite, hypersthene and augite, and olivine. The felspars are the dominant phenocrysts, and occur in crystals which are characteristically vermiculate from resolution. The proportions of olivine and pyroxene, on the other hand, are variable. When the one is abundant, the other is generally scarce.

Anorthoclase occurs as only occasional, large and generally composite phenocrysts, and is always highly vermiculate. Sometimes resolution has gone so far that only a "brain structure" of the original crystal remains. The dominant felspar is a labradorite (Ab_{40}), which is usually less vermiculate than the anorthoclase. In both cases the marginal zone generally has a composition similar to that of the groundmass felspar, so that it forms a clear margin about a vermiculate core. The more lath-like of the labradorite phenocrysts sometimes show fracturing from differential movement.

The hypersthene, like the anorthoclase, has a variable distribution, being much more abundant in some thin sections than others. It is particularly prominent in specimens from the south-west of Mt. Gisborne. It is usually pleochroic in weak tints of green and pink, with (—) 2V between 60° and 90°, indicating a composition about (En_{70}). It is invariably rimmed with augite. The width of such rims varies from a mere line to as much as the width of the enclosed hypersthene, and frequently consists of an aggregate of small granules and prisms of augite accompanied by iron ore. The dominant pyroxene is an augite (2V greater than 45°) which tends to be idiomorphic, and sometimes has a marginal zone not cleared of iron ore inclusions. It is colourless to brownish, and shows a tendency to segregate into clots.

The olivine is always corroded, and is sometimes partly altered to serpentine, but never to iddingsite. In the sections in which they are scarce, the olivine crystals are sometimes rimmed with granular pyroxene, after the manner of the hypersthene crystals. Where they are numerous, however, such rims are absent. Occasionally crystals of corroded olivine may be completely enclosed within crystals of augite, so that there can be no doubt that the augite began to crystallize considerably later than the other phenocrysts. Rarely one also observes

rounded xenocrysts of quartz fringed with small, more or less radially arranged prisms of augite; and in one section a large crystal of apatite, with fibrous inclusions, pleochroic from brown to black, was present.

The groundmass, which consist of plagioclase laths, augite granules, grains of iron ore, apatite needles, and a variable amount of green glass, frequently has a distinctive orthophyric appearance. This derives from the tendency for the labradorite laths (Ab_{50}) to occur as short, stumpy prisms (0.2 to 0.4 mm. x 0.1 mm) which abut against one another without any parallel arrangement, while the much smaller pyroxene and iron ore granules (0.1 x 0.1 mm.) are relegated with the green glass to the interstices. In those specimens in which the felspar laths are not so large in respect to the other constituents of the groundmass, this distinctive appearance is lacking.

The analysis of a typical specimen (Table I., No. 6) shows that despite the obvious mineralogical affinities with the trachyandesites, this rock is not greatly different in composition from the other varieties of basalt in the area. The higher CaO content, reflecting the numerous labradorite phenocrysts, in conjunction with the relatively high SiO_2 and the low Al_2O_3 and MgO, gives the analysis considerable resemblance to that of a tholeiitic-basalt, a point which is of some significance, as will be indicated later.

OLIVINE-AUGITE-HYPERSTHENE-BASALT.

This variety is known only as an inlier exposed in the bed of Campbell's Creek, in the north-east of the area mapped. It is dark, greenish rock, showing phenocrysts of felspar, olivine, and augite. The felspar phenocrysts consist of labradorite and anorthoclase. The labradorite (Ab_{45}) crystals are all columnar in shape, and are generally rounded at the corners, sometimes to the extent of being lens-shaped. Sometimes they have been corroded so as to form re-entrants along their length. They are accompanied by less numerous but extremely vermiculate crystals of anorthoclase.

The pyroxene phenocrysts all appear similar in ordinary light, being brownish with a tinge of violet. Generally they consist of a core of corroded pyroxene, with a narrow fringe of slightly more violet colour, which is charged with minute particles of iron ore, like the pyroxene phenocrysts in the main flow from Mt. Bullengarook. All show extinction angles of 25°–30°. When their optic axial angles were observed, however, some appeared to have 2V about 60°, while occasional crystals had a lower 2V (about 45°). A slide of this rock was kindly examined for me by Mr. Paterson of Otago University, who measured the optic angles on a Universal Stage. He found that in the main they had 2V ranging from 53°–55°. One crystal,

however, showed (—) $2V = 70 \pm 5°$, indicating hypersthene, while another showed a (+) $2V = 40°$, indicating a pigeonite. He also noted that the 2V value was higher in the central part of one augite than on the margin, the range being from $2V = 55°$ to $2V = 47°$. He also attempted to make measurements on the fine-grained pyroxenes of the groundmass. Four measurements were obtained ($2V = 81°–86°$), which suggest that some hypersthene (bronzite) occurs among the groundmass pyroxene, in addition to diopsidic augite.

TABLE I.

——	1.	2.	3.	4.	5.	6.
SiO_2	60·94	56·73	56·90	48·68	49·50	48·15
Al_2O_3	14·46	15·24	15·03	15·32	16·09	13·80
Fe_2O_3	1·23	2·80	2·98	6·71	3·92	1·77
FeO	5·29	6·11	5·90	7·36	6·19	9·66
MgO	2·49	3·91	3·29	6·88	7·11	6·93
CaO	3·65	6·53	6·45	5·99	13·30	10·10
Na_2O	4·95	3·39	3·00	1·44	1·47	2·91
K_2O	3·96	2·97	2·79	1·04	0·29	1·29
H_2O + ...	0·78	0·20	0·32	1·10	0·10	0·71
H_2O −	1·45	1·48	1·21	2·90	0·21	1·90
CO_2	tr.	nil	nil	nil	nil	0·05
TiO_2	0·45	0·75	1·60	1·87	1·95	2·00
P_2O_5	0·02	0·32	0·02	0·05	0·02	0·15
MnO	0·06	0·21	0·07	0·17	0·14	0·06
TOTAL ..	99·73	100·64	99·56	99·51	100·27	99·48

1. Hypersthene-trachyandesite, Allot. xi., Parish of Gisborne.
2. Hypersthene-trachyandesite (De Fegley's flow), Allot. xvii., Parish of Gisborne.
3. Hypersthene-trachyandesite, third flow from surface, Giant's Grave, Jackson's Creek, Gisborne.
4. Hypersthene-basalt, xenolith in trachyandesite, Allot. xx., Parish of Gisborne.
5. Hypersthene-gabbro (norite), block of cognate xenolith in trachyandesite, spoil heap from mine shaft on the Campaspe Deep Lead, near Kyneton.
6. Hypersthene-augite-olivine-basalt (Gisborne type), bank opposite cave at Couangoult, Allot. xxxiii., Parish of Gisborne.

Analyst: A. B. Edwards.

Another surprising feature of this rock is that the plagioclase laths in the groundmass consist of oligoclase (Ab_{75}). It seems highly probable that this rock belongs to, or is associated with, the trachyandesite group. It underlies the iddingsite-basalts, and is not far distant from the Giant's Grave trachyandesite.

B. NORMAL DIFFERENTIATES.

OLIGOCLASE-BASALTS.

Oligoclase-basalt occurs as a flow extending northwards from Mt. Bullengarook, along Hassed's Creek to beyond its junction with the Slate Quarry Creek; in the bed of Jackson's Creek both upstream and downstream from the Calder Highway bridge at Gisborne, where it underlies the Church Hill olivine-basalt; and along Murray's Spur, south-west of Mt. Gisborne, where it underlies the Gisborne type of olivine-basalt.

In hand specimen the oligoclase-basalts are extremely fine-grained and sometimes fissile. Phenocrysts are practically absent, although olivine occurs as scattered microphenocrysts. The bulk of the rock is a fine plexus of plagioclase laths, augite prisms, iron ore and colourless glass. The plagioclase laths mostly show straight extinction, but some show angles up to 10° in the symmetrical zone, indicating that they have the composition of basic oligoclase (Ab_{75}). Flow structure is sometimes well marked, but is never as pronounced as in the typical oligoclase-basalts (macedonites) of the Macedon district. The rock in the bed of Jackson's Creek is particularly fine-grained. Calcite is sometimes present in amygdules of several coarse crystals, or intergrown with the felspar laths in ophitic fashion.

An analysis has been made of the rock from Murray's Spur, and is shown in Table II., No. 1. The high figure for CaO in this analysis is due to the abundant calcite in the rock (CO_2 2.11). The MgO is also high, and is reflected by the presence of olivine in the rock. This, in conjunction with the relatively basic nature of the plagioclase, has led to the rocks being classified among the more basic group of olivine-oligoclase-basalts (8, p. 272). With increase of olivine content and further basification of the plagioclase, this rock would grade readily into the type of olivine-basalt found between Dohoney's Corner and Little Scotland.

Attention may be drawn here to the peculiar rock forming the chilled margin (on the western side) of the limburgite-basalt flow in Toolern Creek. As will be seen from Table II., No. 9, the composition of this rock approximates in many respects to that of an oligoclase-basalt, combined with the features of a limburgite. In thin section it appears somewhat altered and carbonatized, as indicated by the high CO_2 content (3.02) of the analysis. Olivine occurs only in small amount in this chilled edge, although it is abundant in the adjacent unaltered limburgite-basalt (Table II., No. 7). Soda, on the other hand, is concentrated in the chilled margin.

ANDESINE-BASALT.

A flow of andesine-basalt, closely related to the oligoclase-basalts, forms a flow extending from beneath the de Fegley's trachyandesite, via Brucedale, to Little Scotland, and thence for a short distance down Jackson's Creek. It also outcrops in Fisher's Creek, at the edge of the trachyandesite.

This rock contains no olivine and only a sparse amount of pyroxene. It consists essentially of microphenocrysts of plagioclase (Ab_{50}) in the form of small sub-parallel laths and square cross-sections, together with an occasional microphenocryst of augite ((+) 2V greater than 45°) set in an extremely fine-grained base of plagioclase microlites (Ab_{70}), rods of iron ore, granular pyroxene, and abundant black glass. The felspar

microlites and iron ore rods are arranged at random and do not show the fluxion structure that characterizes the felspar phenocrysts, indicating that the base was wholly glassy at the time of extrusion. In places the iron ore has aggregated and developed micro-ophitic intergrowths with the groundmass plagioclase. In some sections the intersertal glass is so crowded with iron ore granules as to appear opaque; but under high magnification it resolves into globules and trichytes of iron ore in a colourless (felspathic) glass. Calcite is prominently developed, as is indicated in the analysis (Table II., No. 2), filling vesicles and interstices. In one section rosettes of small pyroxene crystals associated with calcite have accumulated at the edge of a vesicle, the crystals growing radially into the vesicle. The augite is presumably of late formation, and of a composition similar to that in the groundmass. One crystal showed an acute bisectrix figure with (+) 2V greater than 45°, indicating a composition more or less similar to that of the microphenocrysts.

This rock is really intermediate between the andesine-basalts and the olivine-poor oligoclase-basalts, and has elsewhere been referred to the latter group (8, p. 270, Table III., No. 5). Further consideration of it suggests, however, that the Na_2O and K_2O contents are somewhat low for a typical oligoclase-basalt, and that the plagioclase is slightly too basic for the rock to be included in that group.

Olivine-basalts.

The varieties of basalt occuring under this heading bear considerable resemblance to the type described elsewhere as the Trentham type of olivine-basalt (8, p. 281), and although their chemical compositions (Table II., Nos. 3, 4) do not altogether conform, may be conveniently regarded as members of that group.

The Church Hill basalt.

This type occurs at Church Hill on the Calder Highway, at the eastern end of Gisborne township, overlying the oligoclase-basalt on the southern side of Jackson's Creek. It also outcrops along the northern bank beneath iddingsite-basalt; and it occurs in the bed of Jackson's Creek beneath the trachyandesite at the Giant's Grave.

It is a bluish-green rock in hand specimen, and somewhat altered. In thin section it is seen to consist of phenocrysts of a magnesian olivine and diopsidic-augite, sometimes aggregated into clots, set in a medium to fine-grained groundmass of labradorite laths, pyroxene prisms and granules, grains of iron ore, and abundant devitrified green glass. The olivine phenocrysts are partially resorbed, and are somewhat altered to green serpentine. The pyroxene crystals often appear to be in a state

of arrested growth, with their ragged margins not yet cleared of numerous small grains of iron ore. The groundmass plagioclase is labradorite, with a maximum extinction angle in the symmetrical zone of about 30°, corresponding to a composition Ab_{45}. Occasionally laths attain the size of microphenocrysts; and sometimes the groundmass pyroxene forms irregular or lens-like patches in which it occurs in ophitic intergrowth with the groundmass plagioclase. The analysis of a typical specimen is given in Table II., No. 3.

Little Scotland Basalt.

A somewhat related flow of olivine-basalt extends from south of Dohoney's Corner to Little Scotland on the south side of Jackson's Creek, and similar rock outcrops on the north side of the Creek at Rosslyn, where it passes under the iddingsite-basalt. The olivine phenocrysts in this rock are quite fresh, and there is an absence of green glass from the base. Pyroxene occurs as occasional phenocrysts, but is restricted in the main to the groundmass, where it tends to occur as clusters of granules associated with grains of iron ore. Occasionally these clusters appear to have coalesced into microphenocrysts. The plagioclase laths of the groundmass appear somewhat less basic than those of the Church Hill basalt, and lie between basic andesine, Ab_{55}, and very acid labradorite, Ab_{50}. Calcite is present filling amygdules, and lining occasional vesicles. It also occurs in the groundmass, in ophitic intergrowths with the plagioclase laths.

The basalt at Rosslyn appears to be intermediate between this flow and the basic oligoclase-basalts. It has most of the features of the Little Scotland basalt, but is relatively free from olivine phenocrysts.

Augite-olivine-basalt.

One of the most distinctive basalts of the district is that forming the main southward flow from Mt. Bullengarook. This consists of numerous phenocrysts of augite, sometimes 1 cm. in length, with fewer crystals of olivine, in a groundmass of labradorite laths (Ab_{45}), augite prisms, iron ore, apatite needles, and felspathic glass. The augite phenocrysts are always rimmed with a narrow margin of granular augite, studded with minute grains or iron-ore. This granular augite appears to be coalescing or growing on to the phenocryst, and had not succeeded in clearing itself of iron ore at the time of extrusion. The same phenomena may be observed in other rocks of the district, both at the margins of the phenocrysts, and in the groundmasses, where the minute prisms of pyroxene seem first to cluster together and then coalesce into larger grains which progressively clear themselves centrally of the minute iron-ore grains that are associated with the prisms of groundmass augite.

The groundmass of the Bullengarook flow has a distinctive orthophyric appearance for several miles from the vent, because in this part of the flow the labradorite laths are much more strongly developed than the other minerals of the groundmass, being as much as five times the length of the pyroxene prisms. As a result, the augite prisms, iron-ore grains, and glass, form, together with plagioclase microlites, a dark base in which the coarser laths stand out. This feature becomes less pronounced as one follows the flow away from its source. The augite prisms and iron-ore granules grow in size, and tend to aggregate into micro-clots, while the felspathic glass crystallizes to an increasing extent. This combined with fluxion texture, detracts from the prominence of the earlier-formed laths of groundmass plagioclase.

A feature of one slide of very glassy rock from the western side of the vent is the presence of a number of minute flakes of biotite, strongly pleochroic from foxy red to pale straw. The biotite seems to have been the last mineral to form.

An analysis of this flow made from a specimen from the north wall of the vent reveals that it is practically identical in composition with the fresh limburgite-basalt of Toolern Creek, except for a slightly higher alumina content and lower titania (Table II., No. 4). Advantage was taken also of the coarseness of the pyroxene phenocrysts to separate sufficient for analysis. The analysis (Table III., No. 2) shows that they are fairly typical aluminous augites, closely comparable with the augite in the Mt. Koroit tuff, and the iddingsite-augite basalt overlying the Giant's Grave trachyandesite at Watson's Creek.

IDDINGSITE-BASALTS.

The more recent lava flows are all iddingsite-basalts, and belong to the widespread groups elsewhere designated as Malmsbury and Footscray basalts (8, p. 280). Three variations can be distinguished.

(1) *Iddingsite-basalts.*

These are finely vesicular, grey rocks, generally showing small phenocrysts of iddingsite in the hand specimen. They occur typically as the Junor's Quarry flow at Mt. Gisborne; at Hay Hill; as the second flow at the Giant's Grave; and as the Funston's Quarry flow, extending south from Mt. Gisborne. In this section they are found to consist of numerous, somewhat corroded phenocrysts of otherwise idiomorphic olivine (0.1–0.25 mm.) which have been altered marginally to iddingsite, in a fine-grained intergranular groundmass of plagioclase laths, pyroxene prisms, iron-ore grains, granules of iddingsite, and sometimes glass. Flow structure is often prominent, as in the Junor's Quarry flow. The felspar laths show extinction angles in the symmetrical zone ranging up to 30°, corresponding to Ab_{45}. The groundmass

pyroxene prisms show extinction angles of 41°—43°, so that they are diopsidic. Very occasionally plagioclase and pyroxene occur as microphenocrysts.

The flow structure is less pronounced in the Funston's Quarry flow, in which the felspar laths tend to be thicker, and the pyroxene tends to occur as granules rather than as prisms. Analyses of the Hay Hill and Junor's Quarry flows are shown in Table II., Nos. 5 and 6 respectively.

(2) *Iddingsite-augite-basalts.*

In this variety both olivine and augite occur as phenocrysts. The olivine crystals range from 1.0 mm. down to 0.1 mm. in diameter. They tend to be idiomorphic, and show alteration to iddingsite. The smaller crystals are generally completely altered to iddingsite, while the larger ones have been replaced by iddingsite at the margin and along cracks. The iron ores are sometimes moulded upon the iddingsite rims.

The augite forms still coarser idiomorphic crystals, from 1 to 2 mm. in diameter, which are colourless to grey-violet. The rims are usually clear, but the central parts are often "spongy" with inclusions of iron ore and iddingsite granules. Occasionally they occur in clots in which the numerous individuals are much smaller than the single crystals. Very occasionally crystals are observed with a core that is pleochroic from greenish to yellowish, and with a low extinction angle. Such phenocrysts as showed an acute bisectrix figure had 2V greater than 45°, indicating that they were diopsidic; and a chemical analysis of a single extra-large crystal from the surface flow near Watson's Creek confirmed this (Table III., No. 3).

The groundmass consists of laths of labradorite (Ab_{40-45}) intergrown with rods of iron ore, granular pyroxene and iddingsite, representing a groundmass phase of olivine. A variable amount of glass occurs in the groundmass.

In some sections the felspar shows a tendency to be microporphyritic, indicating a gradation between this variety of iddingsite-basalt and group (3). Still more rarely a large crystal of enstatite is present, or a large vermiculate plagioclase.

This variety occurs at Mt. Bullengarook below the main flow, and at Haires Hill, Magnet Hill, and Beattie's Hill. The flow from McGeorge's Hill contains numerous plagioclase phenocrysts and is intermediate between this group and group (3) below.

(3) *Iddingsite-augite-plagioclase-basalt.*

This rock occurs as the surface flow at the Giant's Grave, where it is of wide extent, at Mt. Kororoit, to the south of the Gisborne Highlands, and at Red Rock and similar hills. It consists of numerous phenocrysts of iddingsitized olivine, augite,

and labradorite in a fine-grained intergranular groundmass. The olivine crystals are idiomorphic, and range from crystals 1.5 to 2 mm. in length, down to small crystals in the groundmass. The iddingsite developed at a late stage, since it post-dates the shrinkage cracks in the larger olivine crystals, and is absent where the olivine is in contact with augite. The augite forms fewer but still frequent idiomorphic crystals ranging from 0.1 to 0.5 mm. in diameter. The central parts of these crystals are generally clear, but they are fringed with a narrow margin that has not cleared itself of iron oxide inclusions. The crystals show a large optic axial angle (2V greater than 45°), and is therefore diopsidic. Analysis of hand-picked pyroxene crystals from blocks of tuff associated with this type of rock at Mt. Kororoit (Table III., No. 1), shows this pyroxene to be a normal aluminous augite, similar to the augite phenocrysts in the iddingsite-augite-basalts, and the augite-olivine-basalt from Mt. Bullengarook.

The distinctive feature of this variety is the abundance of slightly rounded phenocrysts of labradorite (Ab_{40}) that occur in it. These are 1 to 1.5 mm. long and 0.2 to 0.3 mm. wide, with well developed lamellar twinning, and less frequently, zoning. They are generally rimmed with a narrow ragged margin of groundmass felspar. The groundmass is relatively fine-grained and intergranular. It is composed of plagioclase laths (Ab_{45-50}) and much smaller prisms of pyroxene (extinction angle 41°—43°), granules of iron ore and grains of iddingsite.

These three varieties of iddingsite-basalt appear to illustrate the manner in which the basaltic magma differentiated. In the one type olivine occurs alone as phenocrysts; in the next olivine and augite together form phenocrysts; while in the third olivine and augite are associated with basic labradorite, which is already beginning to re-dissolve. Presumably the plagioclase was the first of the three minerals to crystallize or begin to crystallize, and accumulated either by sinking or more probably by floating. Subsequently olivine began to crystallize and sink, giving rise to a graded MgO content within the magma; and was later joined by augite.

Limburgites and Limburgite-basalts.

Limburgite and limburgite-basalts occur on the south-western side of Mt. Gisborne, in the valleys of the Djerriwarrh and the Toolern Creeks respectively, where they attain thicknesses of over 50 feet.

The limburgite consists of crystals of olivine, which are either fresh or only slightly iddingsitized, and have idiomorphic outlines, accompanied by smaller prisms of greenish augite with narrow rims of titanaugite set in a groundmass of similar but still smaller prisms of augite, octahedra of magnetite, and brown glass. In some sections the magnetite crystals are almost as large as the

augite prisms; in others the augite tends to show stellate growth. It has a 2V greater than 45°, so that it is probably rich in lime. Occasional xenocrysts of quartz occur as rounded grains rimmed with minute columnar prisms of pyroxene. Under high magnification the brown glassy mesostasis is seen to consist of colourless glass crowded with trichytes of iron oxide and minute prisms of violet augite. In patches the colourless glass has crystallized as felspar.

TABLE II.

—	1.	2.	3.	4.	5.	6.	7.	8.	9.
SiO_2 ..	51·59	51·82	49·83	45·40	52·01	49·25	45·81	46·28	46·24
Al_2O_3 ..	14·52	15·15	13·76	14·23	13·50	13·87	12·45	13·63	12·83
Fe_2O_3 ..	2·15	1·78	4·77	6·77	6·25	6·78	9·20	5·08	5·15
FeO ..	8·59	8·69	7·77	7·41	4·82	6·29	2·86	8·90	6·35
MgO ..	4·11	3·62	5·76	8·06	8·48	7·24	8·83	8·38	3·63
CaO ..	7·49	7·97	7·05	9·05	7·81	8·46	10·00	9·38	10·48
Na_2O ..	3·45	3·03	2·93	2·68	2·74	2·95	2·86	2·75	4·41
K_2O ..	2·10	1·41	1·84	1·14	1·17	1·76	1·07	2·43	1·64
H_2O +	0·98	1·37	0·50	1·20	0·67	0·12	1·97	0·21	1·10
H_2O −	1·10	0·77	1·95	0·95	0·24	0·85	1·55	0·47	1·45
CO_2 ..	2·11	1·42	nil	0·10	nil	0·05	nil	nil	3·08
TiO_2 ..	1·35	2·10	1·87	1·25	2·20	2·01	2·80	2·31	1·70
P_2O_5 ..	0·81	0·31	0·78	1·25	0·39	0·08	0·69	0·28	1·32
MnO ..	0·16	0·16	0·29	0·17	0·07	0·27	0·21	0·23	0·23
Cl ..	0·04	0·03	..	..	tr.	..	0·04	..	0·07
S ..	0·04	nil	..	..	tr.	..	nil	..	nil
BaO ..	0·03	0·03	..	..	..	..	0·04	..	0·05
TOTALS	99·90	99·66	100·10	99·66	100·38*	99·98	100·38	100·31	99·73

* Li_2O nil, CoO, NiO 0·03.

1. Olivine-oligoclase-basalt, west end of Murray's Spur, west-south-west of Mt. Gisborne, Parish of Gisborne. (*Quart. Journ. Geol. Soc.*, xciv., p. 271, Table III., No. 8.) A. B. Edwards.
2. Andesine-basalt, north-east corner of Allot. 25, Parish of Gisborne. (*Quart. Journ. Geol. Soc.*, xciv., Table III., p. 270, No. 5.) A. B. Edwards.
3. Olivine-basalt, Church Hill, Allot. 2, Parish of Gisborne. A. B. Edwards.
4. Olivine-augite-basalt, north side of Mt. Bullengarook (main flow). A. B. Edwards.
5. Iddingsite-basalt, Hay Hill. (*Bull. Geol. Surv. Vic.*, No. 24, p. 35.) A. G. Hall.
6. Iddingsite-basalt, Junor's Quarry, Allot. 17, Parish of Gisborne. A. B. Edwards.
7. Limburgite-basalt, Toolern Creek, Sect. 19, Parish of Yangardook. (*Quart. Journ. Geol. Soc.*, xciv., p. 290, Table IX., No. 1.) A. B. Edwards.
8. Limburgite, Djerriwarrh Creek, Allot. 5, Parish of Gisborne. A. B. Edwards.
9. Marginal rock of limburgite-basalt flow, Toolern Creek, road from foot of the Breakneck, Parish of Yangardook. (*Quart. Journ. Geol. Soc.*, xciv., p. 270, Table III., No. 6.) A. B. Edwards.

The limburgite-basalt flow in Toolern Creek differs from the Djerriwarrh limburgite in two respects. A proportion of the glass has crystallized out as plagioclase laths or microlites of composition about Ab_{55}—Ab_{50}. In addition the idiomorphic crystals of olivine are completely altered to iddingsite. The otherwise close similarity of the two rocks is shown by a comparison of their chemical analyses (Table II., Nos. 7 and 8). A third specimen which was analysed, from near the extreme edge or base of the limburgite-basalt in Lower Toolern Creek, is an extremely difficult rock to classify. The olivine crystals in it, which were distinctly less numerous than in the central parts of the flow, are much altered, and a considerable amount of calcite is present. The base

is more glassy, moreover, and corresponds to the true limburgite of Djerriwarrh Creek in the practical absence from it of felspar. On the other hand, the analysis (Table II., No. 9) of this chilled edge of the Toolern limburgite-basalt is in many respects comparable with that of an oligoclase-basalt, and would be so classified if no account was taken of its field occurrence.

Mineralogy.

PYROXENES.

Augites.

The common pyroxene in the Gisborne rocks, apart from the trachyandesites and closely allied types, appears to be a diopsidic augite. Approximate measurements of 2V were made whenever a crystal was found which showed an acute bisectrix figure; and these always gave values of 2V greater than (+) 45°, indicating diopsidic augite. In this the author follows Kuno's (17) use of the name pigeonite for monoclinic pyroxenes with (+) 2V less than 45°, and the name augite for those with (+) 2V greater than 45°. These measurements were confirmed for me by measurements of 2V of pyroxenes in the Campbell's Creek flow, made on a universal stage by Mr. O. D. Paterson of Otago University, New Zealand, through the kindness of Professor W. N. Benson. Mr. Paterson found that the augites showed (+) 2V of from 53° to 55°, with a tendency to be more pigeonitic at the margins than in the centre. One crystal had 2V = 55° in the centre and 2V = 47° near the margin. This would suggest that the groundmass pyroxene tends to be more pigeonitic than the phenocrysts, bearing out Barth's (2) observations.

The occurrence of large phenocrysts of pyroxene in several of the lava flows provided an opportunity for further check by determining their chemical composition. Clean samples for analysis were obtained from a block of tuff at Mt. Kororoit (south of the area mapped), from the Mt. Bullengarook (main flow), and from the iddingsite-basalt near Watson's Creek. The analyses (Table III., Nos. 1, 2, 3) show that all three are aluminous augites of generally similar composition.

It was not possible to make a direct comparison of the composition of the groundmass pyroxene in any of these rocks with those of the phenocrysts, owing to lack of means of achieving the necessary separation of the two pyroxenes. Recourse was made, therefore, to a specimen of olivine-oligoclase-basalt from Murray's Spur, thin sections of which appeared to contain very few phenocrysts of pyroxene. This rock was crushed to minus 100 mesh, and the ferromagnesians separated in bromoform in a hand centrifuge. The heavy fraction was re-centrifuged, dried, and the free iron oxides removed magnetically. It was then allowed to stand in cold concentrated hydrochloric acid for one month to dissolve the olivine associated with the pyroxene, after which it was washed, dried, and again centrifuged with bromoform to remove gelatinous silica produced by the breakdown of

the olivine, and any remaining felspar. On examination under the microscope it appeared to be practically free from olivine or felspar. A considerable amount of iron ore remained, however, as minute inclusions in the pyroxene. As only a small quantity of material was left, it was analysed without further treatment.

Table III.

Pyroxenes and Olivine from Gisborne District.

—	1.	2.	3.	4.	5.
SiO_2	48·80	48·31	47·5	47·81	39·17
Al_2O_3	4·93	6·39	6·0	5·64	nil
Fe_2O_3	4·30	0·30	10·71	19·55	nil
FeO	8·37	8·28			9·88
MgO	14·57	14·15	14·3	10·85	49·48
CaO	17·60	18·19	19·5	13·16	nil
Na_2O	0·40	0·55	..	..	n.d.
K_2O	nil	0·25	..	..	n.d.
H_2O	0·15	0·30	..	..	1·00
TiO_2	1·20	2·37	0·5	3·40	nil
P_2O_5	tr.	tr.	nil	tr.	nil
MnO	0·17	1·13	1·5	0·07	0·41
Totals ..	100·49	99·46	100·0	100·48	99·94
CaO/MgO ..	1·208	1·285	1·294	1·213	

1. Pyroxene from tuff, Mt. Kororoit (similar pyroxene abundant as phenocrysts in lava flow).
2. Pyroxene phenocrysts, Mt. Bullengarook flow (Analysis No. 4, Table II.).
3. Pyroxene, large phenocryst (0·2 gm.) in basalt near Watson's Creek, Gisborne.
4. Contaminated groundmass pyroxene (0·3 gm.) from olivine-oligoclase-basalt, Murray's Spur, Gisborne.

Sample contained numerous micro-inclusions of iron ore, which accounts for the high FeO value. Only the CaO/MgO ratio can be compared with Nos. 1–3.

5. Olivine from iddingsite-basalt, Magnet Hill, Gisborne.

Analyst: A. B. Edwards.

Table IV.

Felspars from Gisborne District.

—	1.	2.
Na_2O	3·85	2·79
K_2O	7·36	0·48

1. Mixed felspars (sanidine, anorthoclase, and labradorite), from trachyandesite, Allot. xi., Parish of Gisborne.
2. Plagioclase from Mt. Kororoit tuff. Similar to phenocrysts in lava flow.

Analyst: A. B. Edwards.

The result is shown in Table III., No. 4, from which it will be seen that the ratio of CaO to MgO in this groundmass pyroxene is not greatly different from the CaO : MgO ratios of the analysed phenocrysts. The Al_2O_3 content is also comparable; but the iron and titania contents cannot be compared, owing to the contamination of the groundmass material with iron ores. It cannot be

assumed, however, that these results disprove Mr. Paterson's observations as to the pigeonitic trend in the later pyroxenes, since in the rock selected it is possible that the augite which might have formed phenocrysts with slower cooling has entered into the composition of the groundmass pyroxene.

Hypersthenes.

The hypersthene, which is present in the trachyandesites and associated rocks, showed a (—) 2V greater than 60° and less than 90° in all the sections on which measurements could be made; and Mr. Paterson, in one measurement on a hypersthene crystal in the Campbell's Creek basalt, obtained a value (—) 2V = 70°, corresponding to ($En_{70}Hy_{30}$). He also detected the presence of a more magnesian hypersthene in the groundmass of this basalt, four measurements showing (—) 2V = 81°—86°, corresponding to a composition about ($En_{80}Hy_{20}$).

Pigeonite.

One phenocryst in the slide of Campbell's Creek basalt examined by Mr. Paterson gave a value of (+) 2V = 40°, indicating that it is a pigeonite, the first to be recorded in the Newer Volcanic rocks.

Olivines.

Approximate measurements of the optic axial angles of a number of olivine crystals were made from sections cut normal to an optic axis. These gave the impression that the olivine was magnesia-rich, with not more than 10 per cent. of $FeSiO_3$. This is borne out by the analysis of hand-picked olivine from a small clot in the iddingsite-basalt of Magnet Hill (Table III., No. 4).

Felspars.

Partial analyses were made of a hand-picked specimen of porphyritic felspar from the acid trachyandesite of Mt. Gisborne, and of plagioclase crystals obtained from a block of tuff at Mt. Kororoit. The felspar from the trachyandesite proved to be composite, consisting of sanidine, possibly anorthoclase, and labradorite. This is clear from the composition as calculated from the partial analysis (Table IV., No. 1). Such a composition would fall in the middle of the immiscibility gap of Alling's (1) felspar diagram.

The plagioclase from Mt. Kororoit is a basic labradorite (Table IV., No. 2), and is presumably similar to the phenocrysts which occur in the Mt. Kororoit and related lava flows.

Apatite.

The occasional large crystals of apatite with pleochroic fibrous inclusions in the acid trachyandesite, the norite xenolith, and the Gisborne basalt are identical with those found in differentiated

rock types at Macedon and elsewhere (8, p. 303). The frequent association of this peculiar type of apatite with basaltic hornblende that is breaking down into aegirine and iron ore has led the author to the opinion that such apatite is a characteristic by-product of this breakdown. It may be noted here that such an apatite was found recently in association with a much altered phenocryst (xenocryst ?) of hornblende in a slide of anorthoclase-trachyte from Macedon district.

Petrogenesis.

Origin of the Trachyandesites.

In an earlier paper (8, p. 314) it was tentatively suggested that the trachyandesites in the Coliban district might have originated through the assimilation of sediments by the basalt magma as it stoped its way upwards in a cupola-like chamber. The Gisborne trachyandesites strengthen this supposition. Their intimate association with the other rock types forming Mt. Gisborne demonstrates beyond doubt their derivation from an olivine-basalt magma. They appear, however, to have followed a different mode of differentiation to that taken by the more usual trachytic and oligoclase-basalt differentiates of the Victorian basalt magma. The trachytic differentiates appear to have developed through the early crystallization of olivine, augite, and plagioclase, accompanied by a tendency for anorthoclase and sanidine to crystallize and float up into the top of the magma chamber. The trachyandesites, on the other hand, have developed as a result of the crystallization of hypersthene (with some augite) and basic plagioclase. This tendency has been superposed upon the tendency for anorthoclase and sanidine to form. The fact that the hypersthene and plagioclase subsequently became unstable and commenced to re-dissolve in the magma, suggests that this superposed tendency was a passing one.

At this stage it is necessary to digress briefly into some general considerations. It is well known that two types of basaltic petrographic provinces exist, and that quite different processes of differentiation develop in each. Kennedy (15) has introduced the terms "olivine-basalt magma type" and "tholeiitic magma type" to describe the parent magmas of these two types of province. The igneous rocks of the Cainozoic Circum-Japan Sea province (20) and those of the islands of Japan (21) respectively, provide excellent examples of the suites derived from these respective magmas. When the CaO and MgO contents of the rocks of these (and similar) suites are plotted against their Al_2O_3 contents, as in fig. 4, the curves obtained show characteristic features and differences. As fig. 4 reveals, differentiation of the undersaturated, or olivine-basalts, results in the removal of CaO and MgO from the more acid differentiates (residual magma)

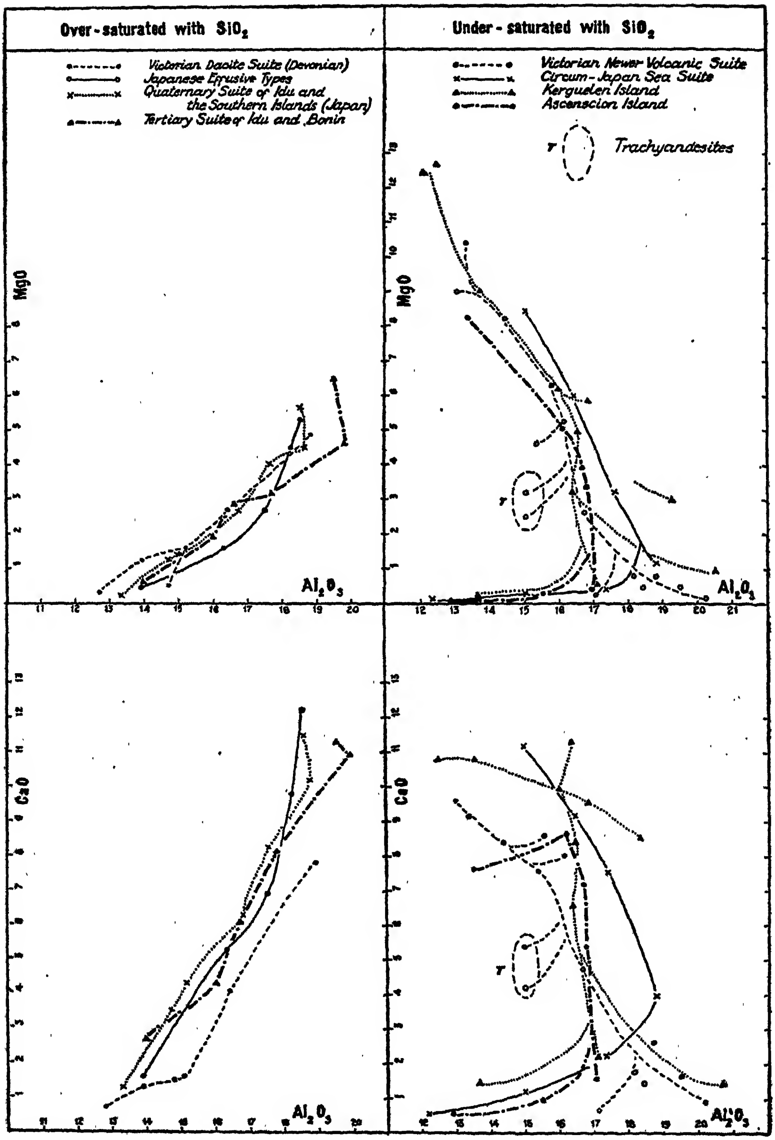

Fig. 4.—Variation diagrams to illustrate the contrasted differentiation of over-saturated and under-saturated basaltic magmas and the anomalous nature of the Victorian trachyandesites.

independently of Al_2O_3, which accumulates in the residuum. The differentiation of the saturated, or tholeiitic magma, on the other hand, leads to the simultaneous removal of CaO, MgO, and Al_2O_3, and yields an acid residuum relatively poor in Al_2O_3.

The olivine-basalt magma is undersaturated with SiO_2 from the outset, and contains abundant MgO. As a result olivine forms abundantly, and this tends to increase the SiO_2 content of the residual magma. Lime, on the other hand, begins to be precipitated partly as augite, a SiO_2-saturated mineral with a low Al_2O_3 content, and partly as basic plagioclase, which is rich in Al_2O_3 but poor in SiO_2. The olivine and augite tend to sink in the magma, whereas the tendency of the basic plagioclase is to float upwards. The trend, therefore, is for the increase of SiO_2 produced in the residual magma by the sinking of olivine to be balanced by the low SiO_2 content of the plagioclase that floats up into the residuum. At the same time only a small amount of Al_2O_3 is removed by either olivine or augite, while a considerable amount of it tends to be carried up into the residuum by the early-formed basic plagioclase. As a further outcome of this tendency, MgO is removed from the magma much more rapidly than CaO during the early stages of differentiation—a fact noted elsewhere (8, p. 311) in connexion with the olivine-basalts of Victoria.

The tholeiite magma, on the other hand, is saturated with respect to SiO_2 from the outset. The minerals which form early are found to be olivine (which forms in restricted amounts and soon re-dissolves), abundant hypersthene, with a lesser amount of augite, and abundant basic plagioclase. The residual magma is considerably more acid than that derived from the olivine-basalt magma, and presumably has a lower specific gravity, so that all these minerals tend to sink in it (at varying rates). The MgO is removed chiefly as hypersthene. The basic plagioclase, being the most Al_2O_3-rich of all common igneous rock-forming minerals, and at the same time the poorest in SiO_2 content of all the plagioclase series, leaves the magma depleted in Al_2O_3 and CaO, but relatively enriched in SiO_2; and some CaO and Al_2O_3 is removed by the augite.

The distinctive feature of the Gisborne (and Coliban) trachy-andesites is that they have been derived by the temporary superposition of a "tholeiitic process of differentiation" upon a basalt magma which had previously been behaving as an olivine-basalt magma. In other words, the undersaturated olivine-basalt magma behaved temporarily as a saturated magma. A possible explanation of this anomaly is provided by Barth (3), who emphasizes the unlikelihood of there being just two types of primary basalt magma of well defined composition, and suggests that it is more probable that primary basalt magma, as a whole, is of a composition which varies locally between these two extremes of

undersaturation and oversaturation with respect to SiO_2. So long as the primary magma is sufficiently undersaturated it will behave as an olivine-basalt magma, while so long as it is sufficiently oversaturated it will behave as a tholeiitic magma. If, however, a local primary magma lies in the more or less narrow range of composition between oversaturation and undersaturation, the manner of its differentiation will be highly susceptible to quite slight changes in the conditions affecting it, and may under some circumstances give rise to mixed end-products.

As has been indicated elsewhere (8, p. 313), the parent magma of the Cainozoic Newer Volcanic Series in Victoria appears to have approached this intermediate composition; for while it has behaved in the main as an olivine-basalt (fig. 4), the less differentiated rocks developed from it show some distinctly tholeiitic features and the trachyandesites reveal a tendency towards a tholeiitic line of differentiation (fig. 4). The suggestion is, therefore, that in certain localities the residuum of this differentiating magma became temporarily oversaturated with respect to SiO_2. This may have arisen under perfectly normal circumstances, such as those which give rise to small quantities of sanidine-rhyolites in association with larger amounts of trachyte and phonolite, as at Kerguelen Island (10) or as in the East Morton district of Queensland (13), or to rocks not quite so rich in SiO_2, such as the solvsbergites associated with trachytes in the Macedon district (18). Such rocks are formed, however, by the further differentiation of trachytic magmas, and are not produced by the crystallization of hypersthene and basic plagioclase. Moreover, they are a stable end-product, and not a temporary phase, which tends to revert to trachyte. On the other hand, in view of the assumption that these rocks differentiated within cupola-like protrusions above the main magma reservoir (7), some local assimilation of argillaceous and arenaceous sediments and perhaps granitic rocks is also envisaged. The numerous xenocrysts of quartz in the trachyandesites are suggestive in this respect. Where the primary magma was thoroughly undersaturated, this might have little or no apparent effect, but where, as in Victoria, the primary magma approached an intermediate composition, such assimilation might be just sufficient to produce a temporary period of local oversaturation which would pass away as more undersaturated magma was added from below. The question may legitimately be asked, why has this not happened at every centre of extrusion in Victoria? The answer may be that it has, to greater or lesser extent, but the products are not always available. The occasional norite-like xenoliths that are found in more or less "normal" lava flows, and the occasional presence of partially resorbed enstatite or hypersthene, may be regarded as indications of this tendency; although, as indicated elsewhere (10, p. 94), they may just as likely be the normal product of the intratelluric stage of differentiation of the magma.

THE DEVELOPMENT OF LIMBURGITES AND NEPHELINITES.

The origin of the small, sporadic flows of limburgite and nephelinite which are a feature of the Victorian olivine-basalt provinces presents a puzzling problem. These rocks, which consist essentially of olivine, pyroxene, and a variable amount of felspathic glass, with or without nepheline, were almost completely liquid at the time of their extrusion (intrusion), as is indicated by their fine-grained texture and the high degree of fluidity required for such "flash injections" as the monchiquite dykes of Bendigo (19). The gradational relationships which exist between these rocks, limburgite grading into olivine-nephelinite within the same flow (Jacobson, 1937, pp. 133-135), indicates a common origin for them. It may be noted also that the rare rock type, woodendite (18, p. 29), differs from the limburgites only in its relatively high potash and soda (3.2% of each).

Moreover, their small bulk, combined with their frequent association in the field with differentiated members of the olivine-basalt suites at what appear to be "centres of differentiation," suggests that they are not in themselves primary magmas but differentiates from the parent olivine-basalt magma; and that their differentiation has taken place presumably within a cupola (7).

Jacobson (12, p. 147) has suggested that such a "limburgitic liquid may be formed in the lower levels of a basaltic magma chamber only by the re-solution of some of the olivine which accumulates in this layer under gravitational control." It frequently happens, however, that olivine microphenocrysts in these rocks are idiomorphic in outline (6, p. 116; 8, p. 292). The olivine-nephelinites are suggested by Jacobson to be "limburgitic liquid" which has undergone a local enrichment in soda, possibly by gas-streaming.

Krokstrom (16) has provided a clue to another possible process by which such rocks could develop. He has shown that in some undersaturated, i.e. olivine-basalt, magmas, the plagioclase begins to crystallize before the olivine, and may even complete its crystallization before the pyroxenes commence to crystallize. As a result, the residual liquid tends to assume a pyroxenic composition. Crystallization of this liquid about the plagioclase gives rise to ophitic textures. Evidence of this tendency in Victorian basalts is found in the development of lens-like patches of ophitic pyroxene intergrown with laths of groundmass felspar, as in the Church Hill basalt at Gisborne, and elsewhere (8, p. 272). There is also plentiful evidence that in some of these rocks olivine and plagioclase have commenced to crystallize (and in some instances completed crystallizing) before the pyroxene began to crystallize. This is clearly the case in the Gisborne basalt and the iddingsite-augite-labradorite-basalts; and it is well shown where rocks of this sort have tachylytic selvedges (9). Lastly, there is the

evidence provided by the occurrence of clots of olivine and "gabbro"—i.e. segregations of olivine and labradorite—that are found occasionally in the limburgites (and monchiquites) themselves, including the Bendigo monchiquites.

If as the result of intratelluric cooling, the onset of crystallization of the residual liquid, which has been enriched in pyroxene constituents in this way, is slow, what will happen? Anorthite, the most basic plagioclase, has a specific gravity of 2.74 to 2.76, and the sodic plagioclases are still lighter. The pyroxenes, on the other hand, have specific gravities ranging from 3.1 to 3.3 for enstatite to 3.5 for hedenbergite, and 3.2 to 4.1 for olivines. If the magma has a specific gravity anywhere approaching the specific gravities of these minerals that crystallize from it, it seems highly probable that the early formed plagioclase would float upwards, leaving an ultrabasic liquid behind. If the temperature of this liquid was relatively low, labradorite or even andesine might crystallize and float away, removing lime, soda, and a certain amount of potash simultaneously; whereas if the temperature of the liquid was relatively high, a correspondingly more basic plagioclase would crystallize, and remove only lime, thus leaving a relative concentration of soda and potash in the ultrabasic liquid. It may be noted in this connexion that even the true limburgites of the Newer Volcanic Province show considerable richness in both soda and potash (8, Table IX., p. 291). Presumably both these stages in differentiation might exist simultaneously in a cupola, since temperature would increase with depth, giving rise to a layer of limburgitic magma overlying and grading down into a layer of olivine-nephelinite magma, which in turn would overlie quite undifferentiated basalt magma.

Summary.

Most of the lava flows that cap the Tertiary gravels and Ordovician sediments of the Gisborne district are differentiation products of an undersaturated or olivine-basalt magma. The complex volcanic hill of Mt. Gisborne, however, is built up of a series of hypersthene-trachyandesites and hypersthene-bearing basalts, in addition to a variety of normal types. The trachyandesites and associated rocks contain numerous phenocrysts of partially resorbed hypersthene and basic plagioclase associated with phenocrysts of sanidine and anorthoclase in a still more advanced state of resorption, phenocrysts of olivine, and numerous xenocrysts of quartz, presumably derived from the intruded sediments. They present the apparent anomaly of a "tholeiitic process of differentiation" superposed on the normal (trachytic) process of differentiation. Since the parent magma from which all these rocks were derived was of a composition intermediate between oversaturation and undersaturation with respect to SiO_2, it is suggested that this local change in the

character of the differentiation may have been brought about by local assimilation of the invaded sediments making the magma saturated. Similar rock types are met with elsewhere in Victoria, but their full development in the Newer Volcanic Series is not yet known.

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[PROC. ROY. SOC. VICTORIA, 52 (N.S.), PT. II., 1940.]

ART. XIV.—*An Unusual Australite Form.*

By GEORGE BAKER, M.Sc.

[Read 14th September, 1939; issued separately 1st July, 1940.]

Among a collection of approximately 550 australites found by the author in the Sherbrook River District, east of Port Campbell, is one rare and unusual form resembling a deep elongated bowl in shape. Only one other similarly shaped specimen has come under the author's notice, and it is a rather larger example from Western Australia (probably the Kalgoorlie District) that was formerly in the collection of Mr. S. F. C. Cook of Kalgoorlie, but is now lodged in the Melbourne University collection (Register No. 3104). A somewhat comparable, but larger example, 10 mm. long and 6 mm. deep, has been described by E. J. Dunn as cup-shaped (2, plate XXIII.), who states that this is the only example approaching such a form that he has seen (2, p. 224).

The dimensions, weights, and specific gravities of the Port Campbell (I.) and of the Western Australian (II.) examples of bowl-shaped australites are shown in table 1.

TABLE 1.

—	Length in mm.	Width in mm.	Depth in mm.	Thickness at Lip in mm.	Thickness at Base of Bowl in mm.	Weight in Grams.	Specific Gravity.
I. ..	7·5	5	3	0·5	0·5	0·135	2·410
II. ..	9	4	3	0·5	0·75	0.149	2·442

Both of the specimens are a brownish bottle-green in colour, the Western Australian example being slightly darker than the one from Port Campbell. Under crossed nicols of the petrological microscope, both of these examples are completely isotropic.

The Port Campbell form was discovered on a gullied portion of the old road, a mile and a half east of the track to Loch Ard Gorge (1, map). The external surface, i.e., the anterior surface, of the specimen was uppermost, this being the usual position of rest of australites on the earth's surface. Both the anterior (external) and the posterior (internal) surfaces are covered with minute bubble pits, and the position of the centrally placed "core" is marked by a small cavity (fig. 1B). No flow phenomena are visible on any portion of the specimen.

The Western Australian example has a very smooth external surface. The position of the "core" at the bottom of the bowl (on the posterior surface), is marked by an elliptical area with well defined but fine flow lines (*c*, fig. 1A), having a complex, fold-like pattern. A pronounced bubble cavity (*b*, fig. 1A), situated to one side of the "core", is seen to possess numerous minute bubble pits on the walls, when examined under high magnification. As in the Port Campbell specimen, the lip of the bowl-shaped form is smooth and rounded (*l*, fig. 1A and B).

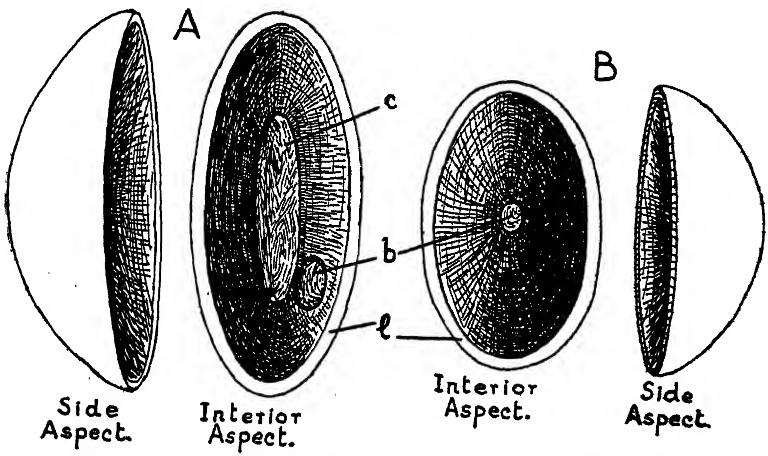

FIG. 1.—Bowl-shaped Australites, A. from Western Australia, x 5½, B. from Port Campbell, Victoria, x 5.
c. = flow-lined core.
b. = bubble cavities.
l. = rounded lip of bowl.

ORIGIN OF BOWL-SHAPED FORMS.

The original forms from which the bowl-shaped australites developed were probably flat and oval-shaped with a broad flange-like area, and a small central core, as in three or four flat examples from the Port Campbell District, which resemble the oval-shaped, flat form illustrated by Dunn (2, plate XXIII., fig. 7). During the end stages of the flight history of the flat, oval-shaped forms, while the australite glass was still in a semi-plastic condition, it is probable that the frictional resistance of the atmosphere against the anterior (forward) surface of the earthward-moving australite, was responsible for turning back the plastic portion of the broad flange to a position almost at right angles to its original position, thus producing a bowl-like form. Figures 1 and 6 on plate XXIII. of Dunn's illustrations (2), which show the flange slightly turned over towards the posterior (back) surface of the australites, may represent early stages in the above-suggested mode of development of bowl-shaped forms. It seems unlikely that the regular curving over

of the flange towards the core could have been produced by impact of the semi-plastic australite glass against the earth's surface, as suggested by Dunn (2, p. 224). Under such conditions, flattening of either one side or the other would be expected, and this is not observed (see fig. 1). Moreover, it is now generally accepted that australites have completely solidified before reaching the ground.

The formation of the flat, oval-shaped australites from which the elongate, bowl-like forms are considered to have been produced is a matter for conjecture. No satisfactory explanation has as yet been advanced to account for their development. The evidence provided by one poorly developed disc-like form, and two nondescript fragments, from the Port Campbell District is rather suggestive of the production of flat, disc-like forms from flat fragments shed from larger forms of australites during flight. These poorly developed examples are flat, somewhat irregular in outline, and show incipient stages in the development of flanges. No intermediary forms between them and the regularly shaped discs, however, have as yet been found, so that the evidence available is by no means conclusive that disc-like australites were formed from fragments shed from larger specimens during flight.

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ART. XV.—*The Sand Dunes of the Portland District and their Relation to Post-Pliocene Uplift.*

By ALAN COULSON, M.Sc.

[Read 12th October, 1939; issued separately 1st July, 1940.]

Contents.

Introduction.

The dune areas of south-western Victoria afford convincing evidence of uplift of the order of 400 feet. The movement began after the Upper Pliocene, and has continued throughout the Quaternary, the most recent elevation being about 10 feet. The dunes comprise both recent and ancient ("fossil") members, and are located in two main areas, viz., the valley of the Lower Glenelg River, and the coastal strip east of Portland. Much of the basaltic Portland promontory is capped by dune sands.

The country has a marked W.N.W. to E.S.E. trend, due chiefly to the coastline between Cape Bridgewater and the mouth of the Glenelg having this direction, but emphasized by the numerous transverse sand dunes parallel to the coast, by the great westerly bend in the Glenelg, by the Wanwin and Swan Lake faults, and by three lines of volcanic foci. In many respects the area can be regarded as a continuation, on a lesser scale, of the "Coorong" area, of alternate dune ridge and swale, which is the dominant feature (Fenner, 1930) of coastal south-eastern South Australia.

Nature and Extent of the Dune Formations.

The lower Glenelg dune-complex is 40 miles wide along Discovery Bay, and extends 25 miles inland. The bare shifting dunes of the two-mile-wide coastal strip gives place inland to older dunes fixed by vegetation, and their amplitude diminishes until north of Dartmoor they flatten out to a sandy plain at an altitude of 200 feet. In this sector the highest altitude attained is 250 feet, and the greatest amplitude of the dunes is about 100 feet.

On the eastern edge of the Glenelg basin, in Kentbruck and Balrook, the dune sands overlie basalt flows and attain altitudes varying between 400 and 500 feet. Similar conditions prevail throughout the Portland promontory, the dune formations ranging in altitude from 50 feet to 400 feet, according to the height of the underlying volcanic rocks, with two exceptionally high points at Mount Kincaid, where sands reach 500 feet, and Mount Richmond, capped by sands at 740 feet.

The dune ridges fringing Portland seldom exceed 100 feet in altitude, and the hinterland east of Mount Clay is a sandy plain, with underlying Tertiary limestone.

Attention is thus drawn to the range in age of the dune formations; it is apparent that the higher level sands of Portland promontory are older than the low-level ridges of Portland Bay, and that the innermost ridges near Dartmoor are older than the bare dunes of Discovery Bay.

The general orientation of the dune ridges is parallel to the coast, which runs roughly N.W.–S.E., and since the prevailing wind is south-westerly, the dunes are transverse ridges. Usually a foredune marks the shoreline, but in the Discovery Bay area, between Bridgewater Lakes and Swan Lake, there is an unusual arrangement of parallel dunes whose direction is oblique to the coast, being west–east rather than N.W.–S.E. No foredune is found in this stretch. The feature seems to be due to the merging of individual crescentic or sub-triangular dunes, whose leeward slopes originally ran N.S. and W.E. to form ridges in which the north–south slopes were obliterated, and the west–east slopes became pronounced. The commonest form (Pl. XIII., fig. 1) is the long irregular, sharp-crested ridge, with the windward side sloping at 10 to 15 degrees, and the leeward at 33 degrees maximum. However, there is endless variety in the size and shape of the dunes, and at either end of a crescentic dune the directions of the steep slopes may seem abnormal, e.g., if the main axis of the dune runs N.W.–S.E., the northerly end may curve round to run west, and at that point the steep leeward slope is towards the north; similarly at the southern end the steep slope may be to the south. But when the whole dune is considered, the dominant steep slope is to the north-east or east.

Wandering dunes, due to the merging of several dune ridges, attain considerable size. They possess flat or only slightly rounded tops, and steep sides sloping in several directions, e.g., north, east, and south. The altitudes may attain 220 feet, but they are composed of several individual dunes, none of which separately would exceed 100 feet amplitude. In no dune was there seen a steep slope to the west or south-west.

Destruction of previously built dunes by wind erosion leaves residual hummocks, fixed by rushes, marram grass, or ti-tree, standing 20 or 30 feet above the general sand-level. These

residuals are common in the coastal strip along Discovery Bay. Residuals of older dunes can be found in many of the wind hollows and in places along the beach, where the consolidated rock, dune-sandstone, or dune-limestone, crops out. Old soil beds are also exposed in places.

That the process of consolidation by compaction and induration begins soon after a dune is built may be observed in many places in the lower Glenelg area. After a spell of heavy rain followed by dry conditions, large flakes and sheets of partly consolidated sandstone may be found in the wind-hollows and troughs of the ridges. These are not portions of residuals, but newly-formed rock. Sometimes they disintegrate, especially those on the surface, but within the dune they are permanent, and form definite bedding planes.

The shores of Bridgewater Bay and Portland Bay are skirted by continuous foredunes, about 20 to 50 feet high and 100 yards wide, and partly fixed by marram grass, rushes, and other plants. A swale or interridge depression from 300 to 800 yards wide separates the foredune from the first dune ridge, which has a core of consolidated dune-rock, whereas the foredune is very largely composed of incoherent sand.

The Narrawong Ridge (fig. 1), which runs at an altitude of 50 feet from Narrawong to Yambuk, is a true dune ridge as defined by Johnson (1919), viz., a beach ridge overlain by aeolian sand. The beach ridge is now at about 20 feet altitude; it

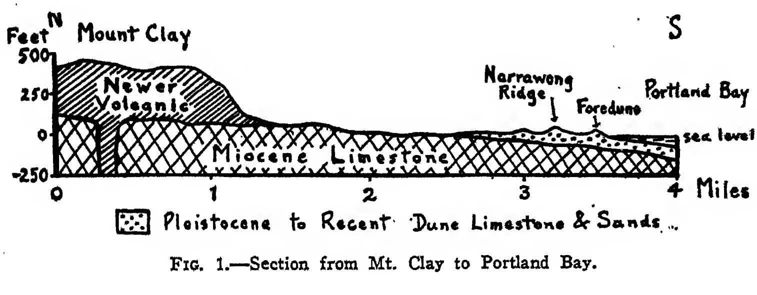

FIG. 1.—Section from Mt. Clay to Portland Bay.

contains abundant shells of species now living on the coast (see appendix) in a bed perhaps 2 feet thick. On either side of the main Narrawong Ridge are parallel raised beach ridges not capped by sand; in addition to their shells, they contain small rounded basalt pebbles. In allotments 4, 5, and 6, Narrawong, these pebbles attain 6-in. diameter, but elsewhere they are about 1 inch.

Between the Narrawong Ridge and the volcanic massif of Mount Clay there is a strip, about three-quarters of a mile wide, of Miocene limestone, with *Ditrupa, Lovenia,* &c. This is exposed

in many places, and is quarried in allotments 47 and 48, Narrawong. East of Darlot's Creek it appears in Castlemaddie P.R. and further east, gradually descending beneath younger sands in the Bessiebelle district.

Considerable progradation of Henty Beach, Portland, can be attributed to the construction of training walls and a breakwater at the mouth of Wattle Creek, causing deposition of silt from the creek and sand brought by long-shore currents from the cliffs. In this manner a width of 4 chains has been reclaimed from the sea within the century of settlement.

A two-mile-wide sand plain stretches from Mount Richmond to Portland South. It is best developed in the Cashmore Heath district, where extensive drainage works to the Wattle Creek were constructed by the Public Works Department in 1916. This plain lies between the basaltic plateau of Gorae and the dunes of Bridgewater, and probably represents the initial sand plain left when the seabed emerged, though the presence of certain inliers of dune limestone, such as Limestone Hill at Cashmore, suggests that denudation has also been effective in reducing the dunes to a fluviatile plain.

About two miles east of the mouth of the Glenelg, in allotment 15A, Glenelg, and at the western end of the Long Swamp, there is a "rake" structure due to the attachment of five or six subsidiary dunes at an angle of 45 degrees to the direction of the main foredune. The effect has been to divide the Long Swamp into a chain of swamps.

Along Discovery Bay is a chain of swamps and lakes, viz., Long Swamp, Bulley Lake, Lake Mombeong (Bong Bong), Malseed's Lake, Swan Lake, and Bridgewater Lakes, which according to some opinions form the remnants of an abandoned course of the Glenelg River. There is no geological evidence, in the shape of old valleys, pebble beds, river cliffs, or the like, that this is so; the swamps are true dune lakes or basins of internal drainage in the swales.

Details regarding the altitude and directions of many of the dune ridges are given on the geological parish plans published by the Geological Survey of Victoria. These include Glenelg, Warrain, Kentbruck, Balrook, Drik Drik, Kinkella, Wanwin, Palpara, Mumbannar, Dartmoor, Wataepoolan, Myaring, Killara, Werrikoo, and Wilkin, but do not cover the area east of the Glenelg Basin. A geological map by Reid (1932, Plate V.), published in Hamilton by Western Petroleum Ltd., covers the area around Portland, and a small area near Heywood was mapped by Kenny (1939). The portions not mapped in detail were sketched in by personal observation extending over three

years, but are subject to correction, particularly in the matter of surface sand. In many places a thin drift of sand masks volcanic rocks, and has been omitted; in others it is several feet in thickness and has been regarded as a definite formation. The accompanying map does not attempt to distinguish between Pleistocene and Recent sands and dune-limestone, though this is done on the parish plans of the Geological Survey.

Types of Sand and Dune-Rock.

All the sands except the most superficial are highly calcareous; the beach sands of Discovery Bay contain 75 per cent. of $CaCO_3$ and the finer sands of Portland Bay contain up to 93 per cent. $CaCO_3$. All are shell-sands derived from skeletons of marine molluscs and echinoderms, finely comminuted, with microzoa such as foraminifera and bryozoa. Where cliffs of Miocene limestone occur, as at Portland, the beach sands are more calcareous than those of the open coast, owing to the additional matter derived from erosion of the limestone. Complete shells are rare on the open beach, but in certain "Shelly Beaches" there are accumulations of pelecypods such as *Notocallista* in commercial quantities. All of the specimens collected, whether from loose sand, old soil beds, or consolidated dune-rock, are similar (see appendix) to species now living in Bass Strait, and may be of any age from Pleistocene to Recent. Identifications were kindly made by Mr. W. J. Parr (foraminifera), Mr. F. Chapman (land shells), Miss I. Crespin (shelly fossils), and the National Museum, Melbourne.

Mechanical analyses (see appendix) of sands were made at the State Laboratories under the direction of Mr. W. R. Jewell. They record the extreme fineness of the dune sands and of many of the beach sands, and indicate the efficient wind-sorting that took place during dune-building.

Chemical investigation was limited to estimations of $CaCO_3$, the method being to boil a weighed sample of sand with HCl. The purity of the sands enabled clay and humus to be ignored. No heavy minerals were observed in any of the sands; the residual grains after digestion with acid were invariably quartz, very fine, even-sized, and clear.

Five types of sand were established, though the differences between them are rather slight:

1. (*a*) Ocean Beach Sand.

Is typified by the creamy-yellow sands of the beaches of Discovery Bay. It consists of fragments of molluscan shells, coarse near the water's edge but finer up the beach, with spines

of echinoids, and microzoa. Fine quartz grains may amount to 20 per cent. of the total. 57 per cent. of the sand passes through 80 mesh but is caught on 100 mesh.

1. (*b*) Dune Sands Derived from Ocean Beaches.

These constitute the unconsolidated dunes inland from the beach of Discovery Bay. They are similar in all respects to the beach sands but are more uniform in grain-size and the particles are more rounded.

2. (*a*) Portland Bay Beach Sands.

Typified by the very fine specked grey-white sands of Henty Beach, Dutton Beach, Nelson Bay, Narrawong, and Tyrendarra. It consists almost entirely of shelly matter, 93 to 98 per cent. $CaCO_3$, and over 50 per cent. of the grains are between 60 and 80 mesh. Recent tetractinellid sponge spicules are common, and distinguish this type.

2. (*b*) Portland Bay Dune Sands.

Similar to the 2(*a*) type, except that the sponge spicules are almost absent. They merge into less calcareous ocean beach sands east of Yambuk.

3. Old Sandy Soils.

Old soil beds are intercalated between the courses of dune limestone. They are often reddish-brown but sometimes almost black, and are seldom more than 1 foot thick. The small land snail *Charopa* is characteristic of the lower soil beds. In the uppermost sand bed capping the cliffs of the Portland promontory there are many shells of the large land snail *Rhytida* and less abundant *Succinea*. Identifications are given in the appendix. $CaCO_3$ content is about 50 per cent., and grain size coarser than the dune sands, mostly between 40 and 80 mesh, and very well sorted. In this type may be included the brecciated old soils, consisting of fragments of old dune-rock and soils, intercalated between normal beds of dune-limestone.

4. Siliceous Sands.

The upper layers of nearly all the dune sands, particularly those that have been fixed for some time, are strongly leached, leaving almost pure quartz, but the percentage of lime increases with depth. Leaching is most pronounced in the swamps and depressions. The thin sandy cappings on the basalt flows usually consists of very fine quartz grains. Such cappings are found on the Kangaroo Range in Balrook and Drik Drik, and on Mount Clay and Mount Kincaid; they probably represent dune sands that have drifted and been leached.

5. Dune Limestone.

Some of the dune-rock has suffered leaching, and is now a friable sandstone; more commonly the hardness has been increased by induration, resulting in travertine which sometimes attains flint-like hardness. However, all the rocks are calcareous and may be included under the name limestone; $CaCO_3$ ranges from 50 to 99 per cent. The rock was derived from pure shell-sand.

In the Werrikooian (?) flaggy limestone at Dartmoor there is a proportion of flakes of white mica, but none is found in the dune limestones.

Structures in the Dunes.

Most of the unconsolidated sand ridges are asymmetrical, with leeward slopes steeper than the windward. The maximum slope does not exceed 33 degrees, which agrees with the measurements recorded by Etheridge (1876), Cornish (1897), Beadnell (1910), Shotton (1937), and Bagnold (1938). Actually, this angle was only rarely obtained where fine dry sand was on the verge of slipping; in most cases the angle of rest was 32 degrees. The windward slopes averaged 7 degrees for long distances, but in the crescentic dunes steeper angles occurred at the curved ends, angles of 25 degrees being obtained on both sides. None of the dunes measured had a steep face longer than 2 chains, though the windward face might be 15 or more chains long.

Some of the arcuate dunes simulate barchans but lack the characteristic horns on the leeward side. Usually individual dunes are somewhat crescentic or sub-triangular in shape. The long ridges have serrated summits, often with curious miniature wind troughs at the very summit, carving it into innumerable small grooves at right angles to its length.

The internal structure of the newly-formed dunes is only partly revealed in the wind-hollows; stratification and incipient compaction are readily noted, particularly in the gently sloping windward beds (Pl. XIII., fig. 2). In the old consolidated dunes, however, admirable exposures in the cliffs enable the rock-courses of dune-limestone to be thoroughly examined. Thus it is possible to work out the windward and leeward slopes of the ancient dunes, using the criterion of Shotton (1937) that dips of 25 to 33 degrees represent leeward slopes, and those less than 25 degrees represent windward slopes. This idea was applied by Shotton and the Lapworth Club to the outcrops and exposures of Bunter (Triassic) sandstone in Shropshire and Worcestershire and revealed that the structures were really ancient barchans built by a prevailing east wind. Applying this method to the outcrops of old dune limestone in the Portland District, the

directions of the steepest dips (rarely more than 28 degrees) were plotted wherever possible, and found to run mainly north-east, with some east and north. Thus they are similar to the modern dunes in having been built up by south-westerly winds.

Terminology for the windward and leeward slopes appears to need standardization: Shotton (p. 542) refers to leeward slopes as "deposition planes" and windward slopes as "planes of erosion", while Bagnold (p. 403) calls leeward slopes "encroachment planes" and windward slopes "planes of accretion".

Occasionally the cliff sections reveal what is apparently the crest of an old dune, resembling the axis of an asymmetrical anticline. An example of this occurs in the cliff above the landslip near the Flat Rocks at Kappa Camp, Nelson Bay. This is probably the feature described by Dennant (1887, p. 227) as a dome with quaquaversal dip, a term the suitability of which was disputed by Griffiths (1887, p. 72).

Minor features in the dune formations, especially where wind erosion has been active, are the "fossil trees", usually several inches in diameter but at times about 18 inches across, with hollow cores. They are due to incrustation about roots of ti-tree, &c., or in the larger "palmetto stumps" (cf. Sayles, 1931) possibly to incrustation around the bases of grass tree (Xanthorrea). Another feature is the miniature karst or irregular-surfaced travertine exposed on the west sides of the cliffs where wind erosion has removed 5 or 6 feet of soil.

After rain, it is interesting to note the leeward growth of the free dunes by the encroachment of dry sand over the moist firm sand on the steep side (Pl. XIII., fig. 3). Vegetation becomes covered by the moving sand and dies; the dead limbs are later exposed in troughs or wind-hollows as the dune migrates. No data are available on the rate of annual migration of the Portland dunes. The water table stands relatively high throughout the area, and the moisture content of the dunes is considerable. Consequently it is in the troughs and depressions that vegetation first gets a hold, usually rushes and grasses followed by ti-tree and larger plants, as described by Audas (1917), Patton (1934), and Cockayne (1911), leading to the ultimate fixation of the dune.

Solution by underground waters is responsible for the formation of numerous small caves, such as those in Batt's Ridges and the Bridgewater district, and at Puralka. In other places there are deep sink-holes (runaway holes), e.g., a sink-hole possibly 200 feet deep at Old Shelly Beach, Cape Nelson. Springs and seepages are common in the deeper valleys and on the coastal cliffs where the water table is intersected; at these points of emergence stalactitic growths are common.

Relation of Dune Formations to other Rocks.

The geological succession in the district is:—

RECENT alluvium, beach sand, dune sand, dune limestone (incipient), shell beds, shingle.
HOLOCENE basalt (Fitzroy River).
PLEISTOCENE dune limestone, shell beds, raised beaches.
LOWER PLEISTOCENE to UPPER PLIOCENE basalt, diatomaceous earth.
PLIOCENE oyster bed, shell beds, flaggy limestone.
MIOCENE marine limestone.
JURASSIC felspathic sandstone and mudstone.

Jurassic sandstone and mudstone outcrop in the Merino district, north of the area investigated, and exposures in the Portland district are limited to two small patches in the banks of the Glenelg and its tributary Stokes River, above Dartmoor. Borings reveal that they underlie the Tertiary limestone at Dartmoor and Mumbannar, and they probably extend south towards Portland, though at a great depth as the Portland bore did not bottom the Tertiary limestone at 2,265 feet. The dune limestone overlies the Jurassic, with or without the intervention of Miocene limestone.

The Miocene limestone is almost universal underground in the southern portion of the area, and outcrops in high spots at Heywood (Kenny, 1939), south of Mount Clay, and near the border at Nelson, as well as being exposed almost continuously along the banks of the Glenelg River, and in the sea cliffs of Whaler's Bluff and Double Corner at Portland. Wherever they come in contact, the dune limestone overlies the Miocene limestone unconformably.

Some difficulty exists with the subdivision of the Pliocene rocks of the area, owing to insufficient palaeontological work. Until recently, the oyster bed and associated shell beds of the Portland cliffs were doubtfully assigned to the Werrikooian (Upper Pliocene), but Miss I. Crespin, Commonwealth Palaeontologist, has classed a collection sent to her by the author as Kalimnan (Lower Pliocene). Details are given in the appendix. The fossils were collected from a road cutting in the face of the cliff near Double Corner, close to "Maretimo" homestead. Dune limestone does not come into contact with this formation.

Apparently the Werrikooian beds are restricted to the valley of the Glenelg. The type area occurs at the junction of Limestone Creek with the Glenelg, north of Dartmoor. There appear to be three beds, viz., upper: flaggy limestone; middle: Oyster bed (Ostrea limestone); lower: shell beds, which are the actual Werrikooian strata. There is probably not much difference in age between the (?) Werrikooian flaggy limestone and the oldest dune formations. After the Werrikooian beds were deposited in the estuary of the Glenelg, the post-Werrikooian uplift brought

these beds into a position suitable for the building of the first dunes, probably in the early Pleistocene period. Possibly the flaggy limestone is part of the first aeolian deposits.

In regard to the relationship of the Newer Volcanic Series to the dune limestone, it must be recognized, as pointed out by Hills (1939, p. 130), that the Fitzroy River basalt is much younger than the other volcanic rocks of the district. In the Tyrendarra Stoney Rises the basalt fills a valley eroded in dune limestone and raised beach ridges associated with the Narrawong Ridge. Inliers of the dune rock and raised shell beds were found in allotment 7B, Homerton, Section B, part of Narrawong, at 25 feet altitude. The locality is shown on Sheet 1 (Helio) of the Fitzroy River Survey made by the State Rivers and Waters Commission in 1933-34. The basalt extends a little east of Wright's Bridge, allotment 56, Narrawong, and according to fishermen it forms a submarine bank trending south-west for some miles in Portland Bay, off Tyrendarra. This basalt is therefore younger than the dune limestone, and is Holocene in age.

The majority of the Newer Volcanic rocks west of Portland are older than the dune limestone since they underlie the dune formations. Their ages may therefore range from Pliocene to Lower Pleistocene. The basal portions of the dune rock often contain embedded pebbles of basalt; these occur in the cliffs of Cape Grant, Cape Nelson, and Cape Bridgewater. Nowhere is there evidence of intrusive basalt in the dune rock, though some earlier observers have stated this, mistaking yellow tuff beds for dune limestone. It should be pointed out that access to the cliffs and shore platforms is easier now than hitherto.

The age of the basalt of the Kangaroo Range at Drik Drik and Balrook has caused considerable discussion, initiated by the different interpretations of the geology by Keble, who mapped the Drik Drik sheet, and J. Foster, who mapped Balrook parish. Keble regards the scarp of the Kangaroo Range as due to erosion by the pre-Werrikooian Glenelg River, thus making the basalts pre-Werrikooian in age. This interpretation was adopted by Sussmilch (1937). Evidence in favour of some antiquity for this basalt is that it carries a heavy forest of Messmate (*Eucalyptus obliqua*) in a deep red soil, with Brown Stringybark (*E. capitellata*) in the sandy patches. J. Foster discovered an important sink-hole in allotment 35, Balrook, which is 80 feet deep. On the east face there is Tertiary limestone capped further up the hillside by the Kangaroo Range basalt; on the west side there is an upper bed of dune limestone about 30 feet thick, resting at an angle of 30 degrees on a red-brown bed consisting of fragments of basalt and scoria set in red ash and clay. Foster regards this lower bed as a fault breccia, but it possesses many of the features of ejectamenta. Scoriaceous basalt 70 feet thick is exposed in the east bank of the Glenelg,

in allotment 3A, Balrook, about 1 mile from the sink-hole, and also on the opposite bank in the parish of Kinkella. Thus the basalt may be at the lower level for a reason other than faulting. The vents from which the main Drik Drik basalt flow was extruded are the twin hills, Mount Vandyke (Good Hill) and Mount Deception, in the parish of Cobboboonee. The rock is a holocrystalline andesine basalt with large white felspars and prominent olivines, similar in many respects to the Pirron Yallock type (Skeats and James, 1937) from the Stony Rises near Colac. By analogy it might be Holocene or Recent in age, but the stratigraphical evidence is at present very incomplete. There is no known bed of Werrikooian between the basalt and the Miocene limestone. Thin cappings of siliceous sands, probably drifted and leached dune sands, occur on the western margins of the basalt. It appears probable that the Drik Drik basalt is pre-dune limestone, and if the fault be admitted, possibly post-Werrikooian.

Basalt is brought into relation with dune limestone along a fault scarp, not previously described, which runs from Swan Lake to near Cape Bridgewater, and has caused a 200-ft. throw to the south. The old dune limestone has been displaced by this amount at the waterfall on Johnstone's Creek above Swan Lake. On the down-throw side the dune rock is exposed at intervals along the coast and in some of the depressions between more recent dunes in the sunkland. The below-sea-level beds of some of the Bridgewater Lakes may be attributed to this fault.

Evidence of Uplift of the Area.

General Uplift.

The pre-Newer Volcanic terrain was an immaturely dissected raised plain of Miocene limestone with relatively high points at Heywood, Condah, Narrawong, and Portland, and a wide bay where the lower Glenelg basin now exists. The coastline was further inland than at present, though its exact position is indefinite. In Lower Pleistocene times, or even earlier, the volcanic eruptions began at numerous vents along three main lines, viz., the northern, including Mt. Eccles, Mt. Eckersley, Mt. Deception, Mt. Vandyke, and vents near the junction of Moleside Creek with the Glenelg; the central, less defined, includes Mt. Kincaid, Mt. Richmond, and Mt. Clay; and the southern comprises Cape Bridgewater, Cape Nelson, Cape Grant, Lawrence Rocks, and Julia Percy Island. Possibly the southerly line of vents was submarine. Much of the extruded matter is tuff, which forms beds nearly 200 feet thick at Yellow Bluff, Cape Nelson, and over 100 feet thick at Cape Bridgewater, Cape Grant, and Lawrence Rocks. As far as is known, there is no evidence of fossils in the tuff, and the massive lava shows no spilitic characters.

The highest point in the district is Mt. Richmond, which is capped by dune sand at 740 feet. The sand is arranged in three tiers or arcuate dunes on the southern and western sides, each tier being about 100 feet high, bringing the base to the same level (400 feet) as the main plateau of the Bridgewater dune rock. The possibility of migration of sand dunes up the sloping sides of Mt. Richmond to form the three high level dunes must be considered. When the general level was 400 feet lower, the volcanic dome of Mt. Richmond would still have projected 340 feet above sea level, and dune sands may have been carried to that height provided that the slope was suitable. It so happens that the sides are very gently sloping, the mount being a large dome covering 4 square miles (see Fig. 2). Migration of dunes up considerable slopes is considered by Hills (personal communication) to have occurred at Cape Otway and Cape Schanck. It is suggested as the cause of the exceptionally high sands on Mt. Richmond.

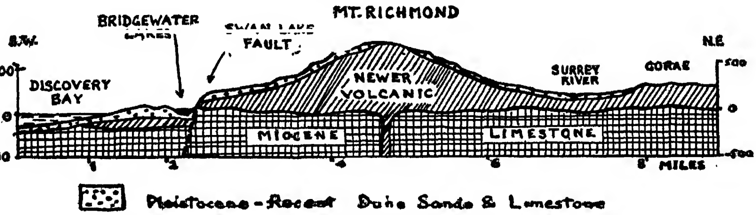

FIG. 2.—Section through Mt. Richmond to show high-level dune sands.

The widespread dune formations at 400 to 500 feet altitude, which cover the basaltic Portland promontory and its westward extension to Swan Lake and Mt. Kincaid, indicate uplift of the order of 400 feet, after allowing 100 feet as the height to which dune formations can be built and levelled off in this district. When the land was 400 feet lower all but the higher volcanoes were submerged. Probably Mt. Richmond (740 feet), Mt. Kincaid (664 feet), Cape Bridgewater (449 feet), and Mt. Clay (622 feet) had their summits above water. As uplift began, marine and aeolian sands were deposited on the shores of these islands at successively lower levels. Thus the higher deposits on the eminences are the older.

When the uplift had proceeded until the plateau of basalt flows was about to emerge, dune building became much more extensive, resulting in the widespread deposits now forming the innermost old dunes. Uplift may not have been continuous owing to the eustatic rise and fall of sea level consequent on release and withdrawal of sea water during the interglacial and glacial epochs of the Pleistocene. Sayles (1931) has pointed out how this affected dune building in the Bermudas, and Hills (1939) has

suggested that similar conditions prevailed in Victoria. Glacial conditions reduced the level of the oceans and accelerated the building of dunes, but interglacial conditions caused a rise of sea level, inhibiting the growth of dunes, which became fixed by vegetation and developed soil beds. In the Portland district a total of five beds (some soil beds and some brecciated-sandstone beds) has been developed, which agrees with the suggestion of Hills that this may be the maximum number in the Victorian dune series.

With continued uplift, the higher dunes became stranded, others being formed further out on the receding shoreline. Not every dune ridge is a stranded foredune, as several ridges were formed at the one sea level, and would be stranded as a group. Wind planation and occasional marine transgressions reduced the summits of these dunes, making a platform of dune rock with fairly level top. Upon this, during interglacial periods, further generations, possibly two or three, of dune rock might develop, separated by the erosion planes and possibly by old soil beds. The complete sequence of dune formations could never be formed in any one place; usually the thickness of dune rock at one place does not exceed 100 feet; the maximum on the coastal cliffs is about 150 feet near Kappa Camp, Nelson Bay.

When the basaltic plateau had fully emerged, the bay which is now the basin of the lower Glenelg had become defined, and so had Portland Bay. During this uplift the formation of shallow water marine sediments in the Glenelg basin occurred, i.e., in Pliocene (probably Werrikooian) times, and was followed by dune building, which is still proceeding. The dune building along the shores of Portland Bay is of late Pleistocene age. Certain faults occurred in the late Pleistocene or Holocene, and that between Swan Lake and Cape Bridgewater let down a strip of country upon which new dunes began to form. Some of the basaltic capes were too steep for new dunes to form on them. Cape Bridgewater was probably the last of the volcanic islands to be tied to the mainland by the growth of sand dunes on the isthmus.

Latest Uplift of About 10 Feet.

The strongest evidence of the most recent uplift is afforded by the raised beaches at Nelson, Narrawong, and Tyrendarra, raised pebble ridges at Point Danger and Blacknose Point, possible raised shore platforms on some of the headlands, and possible raised marine caves in the Bridgewater district. The combined evidence points to a very Recent elevation of the order of 10 to 15 feet.

The raised beach at Nelson is shown on the geological parish plan of Glenelg, in allotment 14, at an altitude of about 10 feet. Similar deposits occur further east in a ridge protruding into the

Long Swamp. The Narrawong ridge, previously described, consists in its basal part of raised shelly beaches at 15 to 20 feet altitude.

On the eastern extremities of Point Danger and Blacknose Point there are pebble ridges at a height of 10 to 15 feet above the present storm beach pebble deposits.

Many low shore platforms, locally termed "Flat Rocks", occur around the base of the cliffs, particularly in the tuff beds, where they are very level. In the basalt, the shore platforms are irregular in level, due partly to variations in original hardness, and partly to differential erosion. No simple correlation is possible between the rock ledges at various heights on the several capes, though doubtless some of them are genuine raised platforms. Jutson (1939) has recently pointed out the possibility of formation of several levels of platforms with sea level at one height, in connexion with the hypothesis of recent elevation of the coast near Sydney, N.S.W. There are well-developed shore platforms on Lawrence Rock and on Julia Percy Island (McCoy Society, 1937).

Two of the caves on the steep eastern face of Cape Bridgewater are of special interest. One has its floor about 30 feet above sea level. It is high, narrow, and does not penetrate far into the cliff, but is inaccessible; thus it is not known what lies under the storm-tossed boulders on its floor. Griffiths claimed (p. 78) that its position was due to uplift, and probably this interpretation is correct. Another cave, the Water Cave, has its floor well below wave level, and has been found to penetrate several hundred feet, leading into a dry cave. This cave was attributed to later subsidence of a wave-cut cave. It may be pointed out that the tuff beds in the cliff are rather steeply inclined and are predisposed to fracture.

At Vance's Beach, Bridgewater Bay, on the north side of the road skirting Bridgewater Bay, there are two caves, almost filled with sand, in allotment 25, Tarragul. They are cut in dune limestone, and the floors are estimated to be 20 feet above sea level, so they are almost certainly raised wave-cut caves. They are separated from the beach by a foredune.

On the steep eastern bank of the Bridgewater Lakes near Lightbody's is a rock face in which several shallow caves appear. The floors are at 150 feet altitude. Bonwick (1857) thought that they were uplifted marine caves; there are shells, flint scrapers and small bones in the sand on the floor, but the shells are of the large edible kind collected by aborigines, and the bones are of mice dropped from hawks' nests in the roof of the cave. These caves are possibly solution caves exposed by the Swan Lake–Bridgewater fault scarp. The rock is dune limestone.

Numerous small caves at Drik Drik, Puralka, and in Batt's Ridges near Portland are apparently solution caves; it might be possible to obtain evidence of uplift from the fossil bones which are known to occur in some of them. Tindale (1933) who applied this method to the caves at Tantanoola, South Australia, correlated the fauna with the stages of development of the sand ridges of South-east South Australia, the period of formation ranging from Upper Pliocene to Recent.

Although terraces are absent on the larger streams, there are two terraces on Wattle Creek near its mouth, in Henty Park, Portland. The higher is about 30 feet altitude, and is well-marked at the entrance to "Burswood" on the south side of the creek; the lower at 10 to 15 feet occurs throughout Henty Park on the north bank. These terrace formations may, of course, have been due to earlier changes in the stream, or may be caused by uplift.

Conclusions.

Evidence of general uplift of the order of 400 feet is afforded by the widespread dune formations at that altitude. Migration to that height and on such a scale is not admitted. Pleistocene glacial and interglacial periods exerted some control on the rate of dune building by their effect on the sea level; this is reflected in the soil beds separating the dune formations. The most recent elevation was of 10 to 15 feet.

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Appendix.

ESTIMATIONS OF $CaCO_3$ (A. Coulson).

BEACH SANDS.	$CaCO_3$ Per cent.
Mouth of Wattle Creek, Portland	93.00
Dutton Beach, Portland, between tide marks	98.75
Pebbly Beach, between tide marks	92.65
Swan Lake Beach, Discovery Bay	75.30
Cape Montesquieu Beach, Discovery Bay	74.75

	CaCO$_3$ *Per cent.*
Dune Sands, Unconsolidated.	
Dunes 170 feet high, Kentbruck	78.80
Dune 420 feet altitude, near old Mt. Richmond S. School ..	71.20
Malseed's Lake, wandering dune	79.70
Bridgewater Lakes, between Lightbody's and Kittson's ..	81.45
Mount Dryden, Cape Bridgewater	69.90
Lake Mombeong (Lake Bung Bung)	77.60
Tyrendarra foredune, 50 feet high	94.05
Mount Kincaid, at 500 feet	56.60
Warrnambool, mouth of Hopkins, foredune 50 feet	92.85
Port Fairy foredune, 50 feet altitude	59.90
Yambuk, foredune at mouth of Eumeralla River	92.60
Dune Rock, Consolidated.	
Bridgewater Lakes, in high caves	98.75
Cape Grant, in cliff face	72.50
Limestone Hill, Cashmore	93.75
400-ft. cliffs overlooking Swan Lake	52.05
Portland Cemetery, quarry near main gate	35.80
Siliceous Sands, from Surface.	
Portland Cemetery	3.22
Blacknose Point, on road	1.15
Rifle Butts, surface	1.00
Rifle Butts cliffs, 20 feet down	5.30
West Gorae, near State School	8.00
Sandy Soil Beds in Dune Limestone.	
Cape Grant, soil bed half-way up cliff	37.75
Cape Nelson, soil bed in cliff	59.90
Cape Montesquieu, soil bed in dune-rock	47.50
Werrikooian Flaggy Limestone.	
Dartmoor Railway Quarry	76.35

Sizing Analyses of Sands (W. R. Jewell, M.Sc.).

Type.	Locality.	On 20 Mesh.	20–40 Mesh.	40–60 Mesh.	60–80 Mesh.	80–100 Mesh.	Through 100 Mesh.
1 (*a*)	Discovery Bay	1·55	4·53	4·21	29·42	57·42	2·87
1 (*b*)	Kentbruck Dunes	1·03	8·92	23·07	56·43	6·45	4·10
1 (*b*)	Bridgewater Lakes, dunes ..	0·13	1·41	8·11	50·47	20·02	19·86
1 (*b*)	Mt. Dryden, 375′ dune ..	0·03	0·19	7·12	71·29	11·37	10·00
2 (*a*)	Shelly beach, between tide marks	0·69	0·93	3·22	46·01	29·15	20·00
2 (*b*)	Shelly beach, 100′ foredune ..	0·04	1·04	4·90	45·81	26·96	21·25
2 (*b*)	Henty beach, foredune ..	0·01	0·04	0·63	52·73	14·14	32·45
3	Cashmore Heath, surface soil ..	1·66	28·79	34·39	23·06	6·38	5·72
3	Cape Grant, old soil in cliff ..	tr.	0·80	47·64	50·57	0·63	0·36
4	Blacknose Point, surface soil ..	0·06	3·01	14·41	43·87	19·81	18·84

Palaeontological Determinations.

Land Mollusca. In uppermost soil bed, Portland Promontory. (F. Chapman.)

Rhytida gawleri Brazier.
Succinea australis Ferussac.
Laoma cf. minima Cox.

LAND MOLLUSCA. In old soil beds, Portland Promontory. (F. Chapman.)

Charopa tamarensis (Petterd).
Charopa spp.
Flammulina sp.

FORAMINIFERA. In uppermost sandy soil, Cape Nelson. (W. J. Parr.)

Uvigerina sp. aff pigmea d'Orbigny.
Discorbis dimidiatus (Jones and Parker).
Discorbis australis Parr.
Discorbis bertheloti (d'Orbigny).
Notorotalia clathrata (Brady).
Cibicides sp. cf. pseudoungerianus (Cushman).
Globigerina bulloides d'Orbigny.
Orbulina universa d'Orbigny.
Elphidium macellum (Fichtel and Moll).
Elphidium imperatrix (Brady).
Quinqueloculina sp.
Triloculina trigonula (Lamarck).
Triloculina insignis (Brady).

COLLECTION FROM THE OYSTER BED, DOUBLE CORNER, PORTLAND (Miss I. Crespin).

FORAMINIFERA—

Cassidulina subglobosa d'Orb.
Orbulina universa d'Orb.
Polystomellina howchini (Chap. & Parr).
Rotalia beccarii (Linne).
Elphidium imperatrix (Brady).
E. crispum (Linne).

ANTHOZOA—

Balanophyllia sp.

POLYZOA—

Cellepora fossa Busk.

PELECYPODA—

Anomia tatei Chap. & Sing.
Nuculana crassa (Hinds).
Clausinella subroborata (Tate).
Glycymeris striatularis (Lam).
Corbula coxi Pilsbury.

GASTEROPODA—

Bankivia howwitti Tate.
Liopyrga quadricingulata Tate.
Eleurnopsis sp.
Cancellaria sp.
Turritella spp.
Bittium sp.
Nassarius sublirella (Tate).
Natica cf. *hamiltonensis* Tate.

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Explanation of Plate.

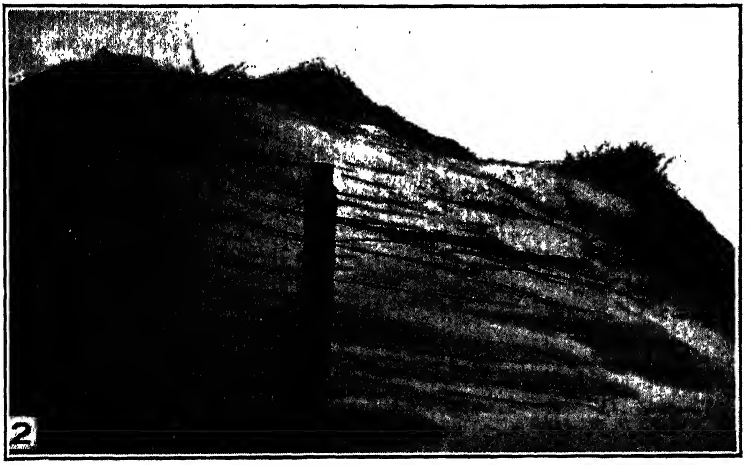
Plate XIII.

Fig. 1.—Sand ridge running east and west, oblique to coast, Discovery Bay, two miles west of Swan Lake.

Fig. 2.—Incipient compaction of sand in layers in a foredune, Discovery Bay, seaward side of Bridgewater Lakes.

Fig. 3.—Lee slope of dune with encroachment of dry sand (white) over-running wet sand (dark), Discovery Bay north of Bridgewater.


1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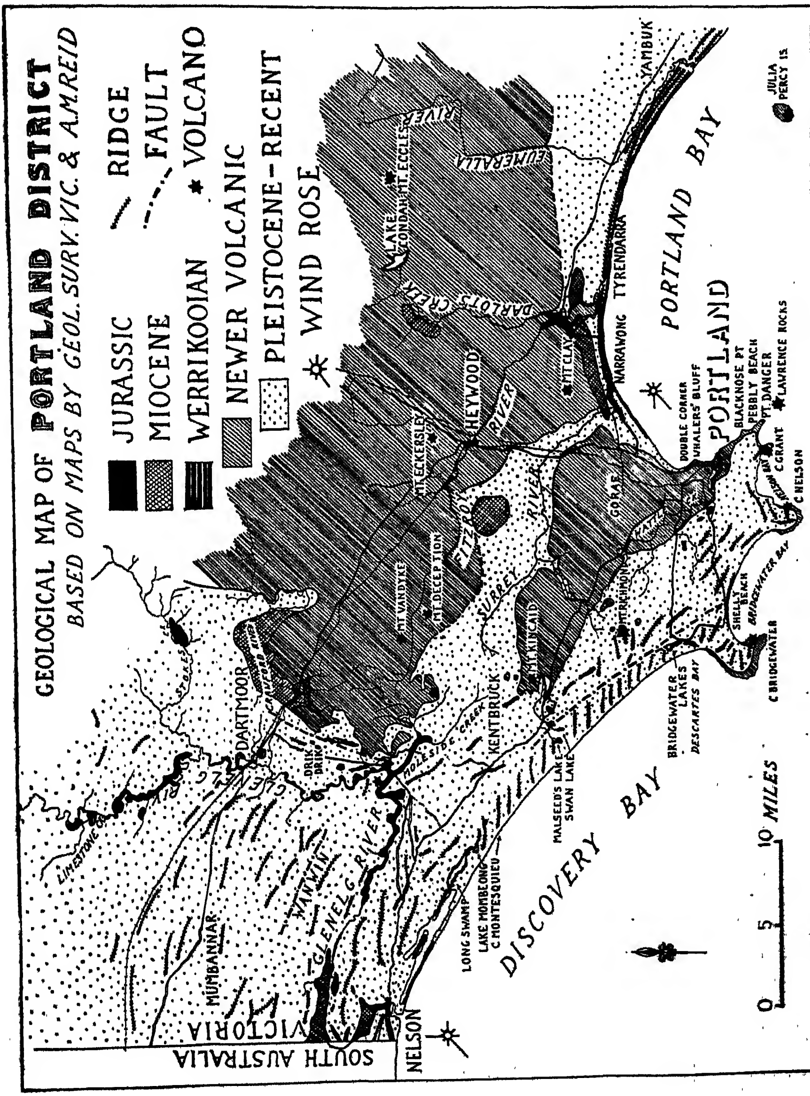

GEOLOGICAL MAP OF PORTLAND DISTRICT
BASED ON MAPS BY GEOL. SURV. VIC. & A.M. REID
JURASSIC
MIOCENE
WERRIKOOIAN
NEWER VOLCANIC
PLEISTOCENE-RECENT
RIDGE
FAULT
VOLCANO
WIND ROSE
DARTMOOR
CRAWFORD RIVER
STOKES
LIMESTONE CK
GLENELG RIVER
DRIK DRIK
WANWIN
MUMBANNAR
VICTORIA
SOUTH AUSTRALIA
NELSON
LONG SWAMP
LAKE MOMBEONG
C. MONTESQUIEU
DISCOVERY BAY
MALSEED'S LAKE
SWAN LAKE
KENTBRUCK
HOLLESIDE CREEK
MT KINCAID
MT RICHMOND
SURREY RIVER
MT VANDYKE
MT DECEPTION
FITZROY
MT ECKERSLEY
HEYWOOD
GORAE
BRIDGEWATER LAKES
DESCARTES BAY
C BRIDGEWATER
SHELLY BEACH
BRIDGEWATER BAY
C NELSON
NELSON BAY
C GRANT
PORTLAND
DOUBLE CORNER
WHALERS' BLUFF
BLACKNOSE PT
PEBBLY BEACH
PT DANGER
LAWRENCE ROCKS
MT CLAY
NARRAWONG
DARLOTS CREEK
LAKE CONDAH
MT ECCLES
EUMERALLA RIVER
TYRENDARRA
YAMBUK
PORTLAND BAY
JULIA PERCY IS
0 5 10 MILES

[Proc. Roy. Soc. Victoria, 52 (N.S.), Pt. II., 1940.]

Art. XVI.—*A Note on the Physiography of the Woori Yallock Basin.*

By A. B. EDWARDS, Ph. D.

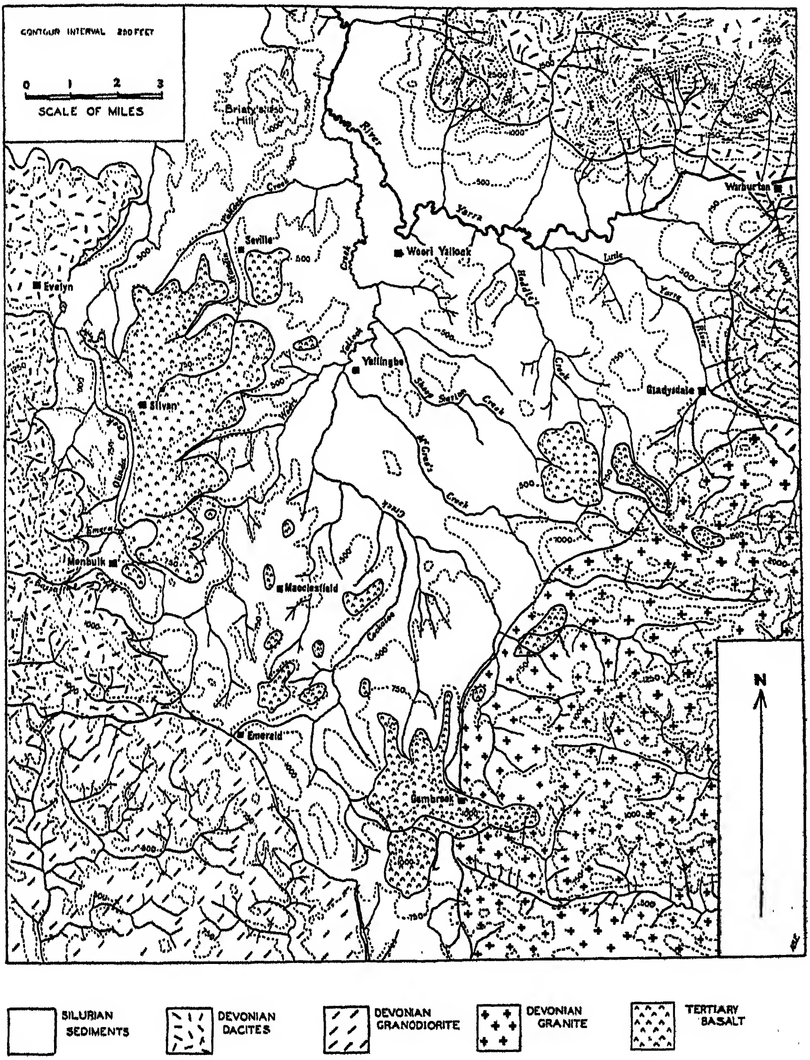
[Read 9th November, 1939; issued separately 1st July, 1940.]

Introduction.

The term Woori Yallock Basin appears to have been coined by Gregory (1903) to describe the relatively low-level area that lies between the Dandenong Ranges, on the west, and the Powelltown Ranges on the east (fig. 1). This area encloses the drainage system of the Woori Yallock Creek, Hoddle's Creek, and the Little Yarra River. It is a topographic basin due to differential erosion, and not a structural one. The floor of the Basin is composed of Silurian mudstones and shales that have been eroded much more easily than the igneous rocks of the Dandenong Ranges or the porphyritic granite of the Powelltown Ranges. The outlet is to the north, to the Yarra Valley, while at the southern end the Basin is closed by a narrow pass, at about 1,000 feet above sea-level, between the converging walls of igneous rock.

Structurally the area has the form of an anticlinal dome (dome in the sense of Thomas, 1939, p. 59), since Melbournian beds occur near Macclesfield, about the centre of the Basin (E. Gill: personal communication), while Yeringian beds occur to the north-east, north, north-west, west, and south-west (Gill, 1939).

In (?) Oligocene times the main valleys across the floor of the Basin were infilled with basaltic lava flows of the Older Volcanic Series, and the drainage reconstituted itself as a series of lateral streams more or less parallel to the pre-basaltic stream courses, and flowing to the north. Erosion of the basalts has progressed until now they occur only as residuals capping the ridges between the valleys. The geological boundaries have been mapped by Easton (1908), and the geology of Figure 1 is based upon his map, while the contours are taken from the Ringwood Sheet of the Military Survey, and the western sheet of the Boy Scout Jamboree Map of 1935. It will be seen that at present the floor of the Basin consists of a series of narrow, sub-parallel ridges, with undulating crests, converging towards the north, and separated by somewhat wider valleys up to 200 feet deep. These valleys and ridges trend at right angles to the walls of the Basin so that over the Basin as a whole their arrangement approximates to a fan-pattern.


CONTOUR INTERVAL 250 FEET
0 1 2 3
SCALE OF MILES
N
Evelyn
Seville
Woori Yallock
Warburton
Yellingbo
Gladysdale
Silvan
Monbulk
Macclesfield
Emerald
Gembrook
Yarra
River
SILURIAN SEDIMENTS
DEVONIAN DACITES
DEVONIAN GRANODIORITE
DEVONIAN GRANITE
TERTIARY BASALT

Previous Observations.

It has been suggested by Gregory (1903), and by Keble (1918), that the pre-Older Volcanic streams in this Basin flowed southwards, through the low pass near Gembrook, to the Koo-wee-rup Swamp; and not northwards to join the Yarra as they do at present. Gregory offered no explanation of the reversal of the drainage from this postulated south-flowing system to the present system other than a very general reference to stream capture; but Keble explained it as due to a retardation of drainage through the "Gembrook bottle-neck" caused by the resistant nature both of the basalt which had infilled the valley at this point, and of the wall rocks of the valley. Such retardation, he suggests, slowed up the development of the system further upstream, and rendered it an easy capture to adjoining river systems.

If this conception of the pre-basaltic streams flowing southwards through the Woori Yallock Basin was correct, the whole of the land north of the Gembrook Pass forming their catchment must have been at a higher level than the level of the Pass at the time when the basalts were extruded. The same volume of water as previously would have found its way through the "bottle-neck" after a short period of lake formation; and despite Keble's suggestion that the lava flows "converged" on this point, there is nothing to indicate that the thickness of basalt at Gembrook is, or was, very materially greater than elsewhere within the Basin. This being so, the rejuvenated drainage of the Basin would have readily breached the lava flow in the "bottle-neck", after which, by undercutting the basalt, it would have established a valley in which it could cut down to the pre-basaltic level, and so, apart from other considerations, make unlikely such an extensive reversion of drainage as visualized by Keble. Moreover, it must be remembered that the adjoining river system—namely, the Yarra System—had also suffered retardation at this time, owing probably to the extrusion of basalt across its valley at Lilydale, and was developing, in the Yarra Valley, extensive river flats which even now are not undergoing erosion (Hills, 1934, p. 169). There are, therefore, grounds for thinking that if there had been a south-flowing drainage system in the Woori Yallock Basin prior to the Older Volcanic eruptions, such a system would continue to exist.

Gregory's Evidence (1903).

Gregory seems to have based his belief in the existence of this south-flowing river system on the following observation (Gregory, 1903, p. 107):—

"Looking across the Woori Yallock Basin (from Mt. Dandenong) to the hills that form its eastern border, we see that

they form a long range sloping to the south; the hill crest is here and there notched and irregular; but a line joining the points on the range has a steady southward slope."

From this he concludes that "at one time this country must have been part of a peneplain with a slope to the south; down this slope rivers flowed at right angles to the course now followed by the Yarra. Remains of the valleys of these older rivers are well marked; thus, the ridge that forms the main watershed of Victoria (the Main Divide) is notched by a river-cut depression —the Kinglake Gap, north of Yarra Glen; and the divide between the Yarra and the rivers of Gippsland is notched by a similar depression east of Gembrook—the Beenak Gap—connecting the basin of Woori Yallock and the Koo-wee-rup Swamp".

Gregory's belief that the dacites and other volcanic rocks of the Dandenong Ranges and the Warburton Ranges were of early Tertiary age "formed at the beginning of the great series of eruptions which ended in the formation of the great basalt plains of Victoria" (Gregory, 1902, p. 213), no doubt caused him to overlook the significance of the difference between the level profile of the Warburton Ranges and the sloping profile of the Powelltown granite massif. This only became apparent after Skeats (1910*a*) had demonstrated the Devonian age of the dacites, when he (1910*b*, p. 188) suggested that "the level-topped, plateau-like character of the dacites" represented "remnants of a former extensive peneplain developed by long-continued subaerial denudation of the igneous and sedimentary rocks before Mid-Kainozoic times", and that subsequent uplift had "led to the dissection of this peneplain and the formation of another at a level of only a few hundred feet above sea-level, the softer sediments being easily base-levelled, and the more resistant dacites preserving remnants of the older peneplain". Hills (1934, p. 160) advances reasons for considering that this older peneplain is of Cretaceous age.

This being so, the true surface of the old peneplain is indicated by the level profile of the Warburton Ranges; while the south sloping surface of the distinctly lower Powelltown Ranges is simply the profile of the present erosion surface on those ranges, and since the granites which form them were probably not exposed at the surface in Cretaceous time, it affords no evidence as to the direction that post-Cretaceous streams would have taken through the Woori Yallock Basin. All that we can determine concerning these is that they must have been determined largely by the positions of the resistant dacite areas. The streams would, therefore, have developed mainly in the softer areas of sedimentary rocks between the dacite areas, much as they are now, and might in this way have become super-imposed on the deeper-seated granites which were probably not exposed at that time.

KEBLE'S EVIDENCE (1918).

Keble's conclusion was based upon his study of lava residuals, particularly those of the Woori Yallock Basin, which, on an uncontoured map, give the appearance of convergence towards Gembrook. Thus he states (p. 158):—

"A large tributary of this last-mentioned stream had its source somewhere north of the Woori Yallock residual, and was probably identical in its headwaters with the Watts. Its course is represented by the 'uncovered residual' of Steel's Range, the Woori Yallock residual, the Gembrook residual, the Pakenham residual, and by a line of conspicuous uncovered residuals disappearing into the Koo-wee-rup fault block towards the trunk stream. Above the Gembrook bottleneck this tributary received a tributary from the north-east; it originated on the westerly slope of Mt. Donna Buang."

When this statement is examined in detail, a number of facts appear which are irreconcilable with the general picture. Thus—

1. Steel's Range (Briaty's Hill), as indicated by Hills (1934, p. 168), owes its prominence to the fact that it is composed of silicified sandstones, more resistant to erosion than the adjacent Silurian sediments. It cannot, therefore, be an "uncovered residual", i.e., the floor of a pre-basaltic valley.

2. The basalt residuals along the upper part of Hoddle's Creek descend successively from 1,500 feet above sea-level to 1,300 feet and 750 feet, going towards the north-west, and Hoddle's Creek and Sheep Station Creek, which also flow in a general north-westerly direction, appear to be laterals of the flow represented by these residuals.

3. The line of basalt residuals extending from near Emerald to north of Macclesfield descends from about 950 feet at the southernmost residual to about 700 feet at the northernmost—a fall of 250 feet in 4 miles. The levels refer to the relatively flat tops of the residuals, since the bases are obscured by soil creep. Moreover, the Woori Yallock Creek and the Cockatoo Creek–Macclesfield Creek have formed as north-flowing laterals to this lava flow, and indicate its northward extension—now marked by an "uncovered residual"—to near Yellingbo, where they junction.

4. At Gembrook the basalt residuals stand at 1,050 feet to 1,100 feet above sea-level, and fall away to the north (1,000 feet). The branch of Cockatoo Creek, which is a lateral to the Gembrook residual, rises south of the southernmost point of the basalt, and flows northwards from this point.

5. The large residual extending from Monbulk to just south of Seville, ranges in height from 950 feet to 700 feet above sea-level. The surface is somewhat irregular, being highest in the central portion near Silvan. It seems probable that this residual

represents not a "confined" lava field, as Keble suggested, but a local "extensive" lava field, infilling the valleys of several streams which rose in the Dandenong Ranges and trended eastwards or north-eastwards, and also covering the interfluves between them. Some of these streams, like Emerald Creek and Sassafras Creek, subsequently crossed and breached the basalt, and joined its eastern lateral, Woori Yallock Creek. Others, like Lyre Bird Creek and Olinda Creek, were ponded into a lake behind the lava flows, and found an escape over a low divide south-east of Evelyn, being thus enabled to form a western lateral to the basalt as the present Olinda Creek.

Conclusion.

From this brief discussion it will be seen that there is no reliable evidence to show that any stream ever flowed southwards via the Woori Yallock Basin towards Western Port Bay. On the other hand, the levels at which the remaining basaltic residuals occur strongly suggest that the pre-Older Volcanic streams, like the present ones, flowed to the north to join the Yarra River. The Gembrook Pass, on this view, is not a river-cut depression but simply a low pass in the divide, such as may be expected in any divide wherever a zone of soft rocks occurs interposed between resistant rocks.

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[Proc. Roy. Soc. Victoria, 52 (N.S.), Pt. II., 1940.]

Art. XVII.—*Further Notes on Certain Marine Deposits at Portarlington, Victoria.*

By J. T. JUTSON and ALAN COULSON.

[Read 14th December, 1939; issued separately 1st July, 1940.]

Introduction.

As the result of criticism of our paper (2) by E. S. Hills (1) we re-visited the sections in September, 1939, and now offer the following remarks thereon.

The Pier Sections.

Our inspection shows that a considerable quantity of recent marine shells has been deposited on the upper part of the cliff face. These shells are clearly due to human agency, having, in all probability, been washed from the surface of the ground above the cliff, by very heavy rains, as we were informed by the Engineer for the Shire of Bellarine, who stated that shells are carried from the beach for use on footpaths. If these were the shells seen by Hills, then he was justified in regarding them as artificially laid over the ferruginous sands.

We desire to emphasize the fact that the shells referred to have been deposited in their present positions since our visits on which our paper was based. At that time there were thin horizontal bands of recent marine shells in the dark-coloured surface sands and in the outcrops of the brown sands some feet below. These bands were only found after close search and, as a result of their mode of occurrence and distribution, we came to the conclusion, after considering the possibility of their occurrence being due to human agency, that they were of the same age as the brown sands.

Recent gullying action shows that the upper dark-coloured sandy beds, containing an abundance of recent marine shells hitherto covered by "wash", have been artificially laid down and that, in addition to the shells, a considerable quantity of the brown sand has been carried farther down the cliff face. In some of these brown sand outcrops, there are thin horizontal shell bands; but most of the shell-bearing brown sand outcrops to which our earlier paper referred have been removed by rain action since that paper was written, so that a re-consideration of the evidence submitted by us is not altogether possible. As a result, however, of our recent investigation, we have come to the conclusion that the shell bands seen by us were the indirect

result of human interference, and our first paper is modified accordingly. Consequently, the age of the brown sands, so far as based on contained fossils, must be left an open question. We would point out, however, that their location and lithology suggest that they are of the same age as the ferruginous beds of Steele's Rock section, whatever that may be.

The Steele's Rock Section.

The criticism of this section offered by Hills was anticipated and answered in our first paper, so that a reply to that criticism seems hardly necessary. We may, however, point out that our re-examination of the section has served to confirm our original conclusion, viz., that the ferruginous beds merge into the calcareous beds, the two being merely phases of the one series. Hills does not discuss the western portion of the section, where the evidence of the unity of the beds is strongest, as we pointed out in our first paper. He rests his disagreement with our interpretation on the relations of the rocks at the eastern end of the section, where he considers that the horizontal calcareous beds rest unconformably on the inclined and current-bedded ferruginous ones. Close examination, however, shows that the planes of stratification of the ferruginous beds can be traced faintly into the calcareous beds, the faintness being due to the fact that the stratification planes have been almost completely obliterated by the approximately horizontal division lines of the subsequently introduced carbonate of lime. In addition, there are, in the calcareous rocks small irregular unaltered patches of the ferruginous beds.

The part of the section just referred to is on the western side of the small headland which lies immediately to the south of Steele's Rock. If the calcareous band be followed round the headland to the eastern side of the latter, it can be seen to die out as an inclined lenticular patch in the yellow earthy limestone which rests conformably upon the ferruginous beds (fig. 1). This lenticle we regard as originally part of the limestone, and

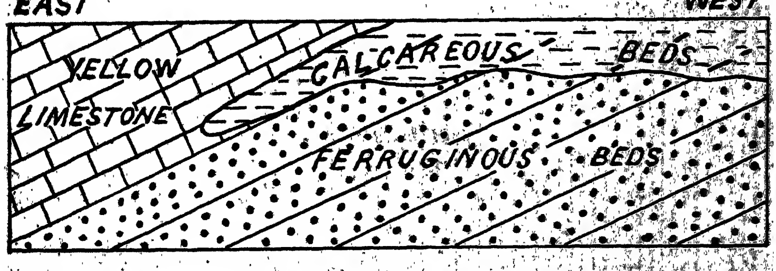

FIG. 1.—Diagrammatic section of the cliffs opposite Steele's Rock, Portarlington. The planes of stratification of the ferruginous beds pass faintly into the calcareous beds.

not as filling a cavity in the latter. There are therefore two sets only of distinct sedimentary beds in the section—the ferruginous sands and the yellow limestone. The calcareous rocks are common to both, but in a very limited degree to the limestone, and are merely an alteration phase of each.

In the calcareous beds, a few feet west of the lenticular patch just noted, we found on our re-examination two Recent marine shells, this being the first discovery of fossils in the extreme eastern end of the section.

The basal beds in the western portion of the Steele's Rock section as a whole, follow the very irregular surface of the Older Basalt, but above, the stratification, although indistinct, approximates in both the brown sands and the calcareous beds towards the horizontal. Deposition, however, was evidently rapid, as shown by the irregular pockets of shells. Even if the horizontality is only apparent and represents the strike of the beds, that does not affect their conformity.

Conclusions.

The want of undoubted fossil evidence as to the age of the Pier beds does not affect the conclusions we have drawn as to the age and significance of the Steele's Rock deposits.. Neither does it affect our inferences as to the age of the upper ferruginous non-fossiliferous beds of the Bellarine and Mornington Peninsulas, and of the district to the east, north, and north-east of Melbourne; nor our proposed subdivision of the post-Tertiary rocks of the Port Phillip Bay district, since we regard the evidence of the Steele's Rock section as sufficient independently to support those ideas.

As a final remark, we desire to correct a misinterpretation of our paper by Hills. He states (p. 132) that we argue that the "Red Beds" of the Melbourne district are Pleistocene and not Barwonian and Kalimnan as formerly believed. Our references in every instance were to the uppermost non-fossiliferous beds, which all authorities have hitherto placed in the Upper Tertiary (pp. 319 et seq.). The Kalimnan age of some of the deposits was challenged by us, but we made no criticism of the Barwonian. That was outside the scope of the paper.

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2. Jutson, J. T., and Alan Coulson.—On the Age of Certain Marine Deposits at Portarlington, Victoria, with a Proposed Subdivision of the Post-Tertiary Rocks of the Port Phillip Bay District. *Proc. Roy. Soc. Vic.*, n.s., xlix. (2), pp. 314-326, 1937.

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Bale, W. M., F.R.M.S, 83 Walpole-street, Kew, E.4 1887
Chapman, F., A.L.S., Hon. F.R.M.S., F.G.S., Threadneedle-street, Balwyn,. E.8 1902
Gault, E. L., M.A., M.B., B.S., 4 Collins-street, Melbourne, C.1 .. 1899
Lyle, Prof. Sir Thos. R., M.A., D.Sc., F.R.S., Irving-road, Toorak, S.E.2 1889
Kernot, Assoc. Prof. W. N., B.C.E., M. Mech. E., M. Inst. C.E., 10 Princes-avenue, East Caulfield, S.E.5 1906
Kershaw, J. A., F.R.E.S., 11 Wrexham-road, Prahran, S.1 .. 1900
Mahony, D. J., M.Sc., National Museum, Russell-street, Melbourne, C.1 1904
Osborne, Prof. W. A., M.B., B.Ch., D.Sc., "Lowestoft," Warrandyte, Victoria 1910
Pratt, Ambrose, 376 Flinders-lane, Melbourne, C.1 1918
Selby, G. W., Glenbrook-avenue, Malvern, S.E.5 1889
Skeats, Prof. E. W., D.Sc., A.R.C.Sc., F.G.S., University, Carlton, N.3 1905
Sweet, Georgina, D.Sc., "Queongo," 64 Mont Albert-road, Canterbury, E.7 1906

Ordinary Members.

Agar, Prof. W. E., M.A., D.Sc., F.R.S., University, Carlton, N.3 .. 1920
Anderson, George, M.A., LL.M., M.Com., 36 Lansell-road, Toorak, S.E.2 1924
Balfour, Lewis J., B.A., M.B., B.S., 62 Hopetoun-road, Toorak, S.E.2 1892
Baragwanath, W., Geological Survey Department, Treasury Gardens, East Melbourne, C.2 1922
Barker, Prof. A. F., M.Sc., 170 Toorak-road, South Yarra .. 1940
Barrett, A. O., 1 Queen-street, Melbourne, C.1 1908
Barrett, Sir J. W., K.B.E., C.M.G., M.D., M.S., 105 Collins-street, Melbourne, C.1 1910
Bull, L. B., D.V.Sc., Animal Health Research Laboratory, Parkville, N.2. 1939
Casey, Dermot A., c/o Melbourne Club, Collins-street, Melbourne, C.1 1932
Cherry, Prof. T. M., B.A., Ph.D., University, Carlton, N.3 .. 1930

Clark, A. M., M.Sc., 9 Grattan-street, Hawthorn, E.2 1940
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Dyason, E. C., B.Sc., B.M.E., 92 Queen-street, Melbourne, C.1 .. 1913
Edwards, A. B., B.Sc., Ph.D., D.I.C., Geology School, University, Carlton, N.3 1930
Esserman, N. A., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3 1923
Gepp, Sir Herbert W., Box 1643, P.O., Melbourne 1926
Grice, J. Hugh, "Highfield," Lilydale 1938
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Hartung, Prof. E. J., D.Sc., University, Carlton, N.3 1923
Hills, E. S., M.Sc., Ph.D., Geology School, University, Carlton, N.3 1928
Jack, R. Lockhart, B.E., D.Sc., F.G.S., c/o Broken Hill Pty Ltd., 422 Little Collins-street, Melbourne, C.1 1931
James, A., B.A., D.Sc., 23 Bayview-crescent, Black Rock, S.9 .. 1917
Jones, Wood, Prof. F., D.Sc., M.B., B.S., M.R.C.S., L.R.C.P., F.R.S., F.Z.S., University, Manchester, England 1930
Jutson, J. T., B.Sc., LL.B., "Darlington," 9 Ivanhoe-parade, Ivanhoe, N.21 1902
Keble, R. A., National Museum, Melbourne, C.1 1911
Lang, P. S., B.Agr.Sc., School of Agriculture, University, N.3 .. 1938
Leeper, G. W., M.Sc., Chemistry School, University, Carlton, N.3 .. 1931
Lewis, J. M., D.D.Sc., "Whitethorns," Boundary-road, Burwood, E.13 1921
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Mackinnon, J. C., Melbourne Club 1938
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Nicholas, Geo. R., 48 Lansell-road, Toorak, S.E.2 1934
Orr, Dr. R. Graeme, M.A., B.Ch., 621 Toorak-road, S.E.2 1935
Orr, Dr. W. F., 8 Collins-street, Melbourne, C.1 1932
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Quayle, E. T., B.A., 27 Collins-street, Essendon, W.5 1920
Rae, F. J., B.A., B.Sc., B.Ag.Sc., Botanic Gardens, South Yarra, S.E.1 1927
Reid, J. S., 498 Punt-road, South Yarra, S.E.1 1924
Richardson, A. E. V., M.A., D.Sc., C.M.G., Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2 1938
Rigg, Gilbert, 20 Finch-street, Malvern, S.E.5 1931
Rivett, Sir David, M.A., D.Sc.. Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2 1911

Rogers, J. Stanley, B.A., M.Sc., University, Carlton, N.3 1924
Sewell, Dr. S. V., 12 Collins-street, C.1 1936
Singleton, F. A., M.Sc., University, Carlton, N.3 1917
Stillwell, F. L., D.Sc., 44 Elphin-grove, Hawthorn, E.2 1910
Summers, Associate Prof. H. S., D.Sc., University, Carlton, N.3 .. 1902
Thomas, Dr. D. J., M.D., 81 Collins-street, Melbourne, C.1 .. 1924
Tiegs, O. W., D.Sc., University, Carlton, N.3 1925
Turner, Professor J. S., M.A., Ph.D., University, Carlton, N.3 .. 1938
Vail, Lieut.-Col. L. E., 485 Bourke-street, Melbourne, C.1 .. 1939
Wadham, Prof. S. M., M.A., Agr. Dip., University, Carlton, N.3 .. 1932
Wettenhall, Dr. Roland R., "Aberfeldie," 557 Toorak-road, S.E.2 1938
White, Dr. A. E. Rowden, 14 Parliament-place, Melbourne .. 1938
Withers, R. B., M.Sc., Dip. Ed., University High School, Parkville, N.2. 1926
Woodruff, Prof. H. A., M.R.C.S., L.R.C.P., M.R.C.V.S., University, Carlton, N.3 1913
Young, Prof. W. J., D.Sc., University, Carlton, N.3 1923

Country Members.

Blackburn, Maurice, M.Sc., Fisheries Section, C.S.I.R., Cronulla, N.S.W. 1936
Caddy, Dr. Arnold, "Chandpara," Tylden, Vic. 1924
Caldwell, J. J., Geological Survey Office, Bendigo, Vic. 1930
Cox, H. M. S., Wombat Park, Daylesford 1931
Crawford, W., Gisborne, Vic. 1920
Glaessner, M. F., Ph.D., c/o Australasian Petroleum Co., Port Moresby, Papua 1939
Harris, W. J., B.A., D.Sc., High School, Echuca, Vic. 1914
Hope, G. B., B.M.E., "Carrical," Hermitage-road, Newtown, Geelong, Vic. 1918
Lawrence, A. O., B.Sc., Dip. For., 509 Ligar-street, Ballarat .. 1931
Mackenzie, H. P., Engr. Commr., R.N. (Ret.), Trawalla, Vic. .. 1924
Mann, S. F., Caramut, Vic. 1922
Quayle, D. S., 33 Gent-street, Ballarat 1939
Ramsay, Urquhart, "Turkeith," Winchelsea 1938
Thomas, D. E., c/o Geological Survey, Mines Dept., C.2 .. 1929
Trebilcock, Captain R. E., M.C., Wellington-street, Kerang, Vic. .. 1921
White, R. A., B.Sc., School of Mines, Bendigo, Vic. 1918

Associates.

Abraham, W. S., Geological Survey Museum, Gisborne-street, East Melbourne, C.2 1929
Aitken, Miss Y., M.Agr.Sc., School of Agriculture, University, Carlton, N.3 1936
Bage, Miss F., M.Sc., Women's College, Kangaroo Point, Brisbane, Qld. 1906
Baker, G., M.Sc., Geology Department, University, N.3 1935
Blake, A. S., 19 Rose-street, Ivanhoe, N.21 1929
Brazenor, C. W., National Museum, Russell-street, Melbourne, C.1 1931

Breidahl, H., M.Sc., M.B., B.S., 23 Chatsworth-avenue, North Brighton, S.5 .. 1911
Broadhurst, E., M.Sc., 457 St. Kilda-road, Melbourne, S.C.2 .. 1930
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Chapple, Rev. E. H., The Manse, Warrigal-road, Oakleigh, S.E.12 .. 1919
Clark, J., F.L.S., National Museum, Melbourne, C.1 1929
Clinton, H. F., Department of Agriculture, Public Offices, C.2 .. 1920
Collins, A. C., 3 Lawrence-street, Newtown, Geelong 1928
Colliver, F. S., 14 McCarron-parade, Essendon, W.5 1933
Condon, M. A., B.Sc., c/o Australasian Petroleum Co., Port Moresby 1937
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Cookson, Miss I. C., D.Sc., 154 Power-street, Hawthorn, E.2 .. 1916
Coulson, A., M.Sc., 42 Gawler-street, Portland 1929
Coulson, A. L., D.Sc., D.I.C., F.G.S., Geological Survey of India, 27 Chowringhee, Calcutta 1919
Cowen, Miss Margot E. H., B.Agr.Sc., 2 Leaburn-avenue, S.E.7 .. 1936
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Elford, H. S., B.E., c/o Tait Publishing Co., 349 Collins-street, Melbourne, C.1 1934
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Fenner, C., D.Sc., Education Department, Flinders-street, Adelaide, S.A. 1913
Ferguson, W. H., 37 Brinsley-road, E. Camberwell, E.6 1894
Finney, J. M., 387 Springvale-road, Forest Hill 1925
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Gordon, Alan, B.Sc., c/o C.S.I.R., Yarra Bank-road, South Melbourne, S.C.4 1938

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Holmes, W. M., M.A., B.Sc., Observatory, South Yarra, S.E.1 ..	1913
Honman, C. S., B.M.E., Melbourne Technical College, 134 Latrobe-street, C.1	1934
Jack, A. K., M.Sc., 49 Aroona-road, Caulfield, S.E.7	1913
Jacobson, R., M.Sc., Woodbine-grove, Chelsea	1937
Jessep, A. W., B.Sc., M.Ag.Sc., Dip. Ed., Horticultural Gardens, Burnley, E.1	1927
Jona, J. Leon, M.D., M.S., D.Sc., Lister House, 61 Collins-street, Melbourne, C.1	1914
Keartland, Miss B., M.Sc., 19 Glen-street, Hawthorn, E.2 ..	1919
Kilvington, T., M.Sc., Physiology Department, University, N.3 ..	1938
Lindsay, Miss Eder A., B.Agr.Sc., Agriculture School, University, N.3	1936
McCance, D., M.Sc., 144 Gatehouse-street, Parkville, N.2	1931
MacDonald, B. E., "The Heights," 127 Banksia-street, Heidelberg, N.22	1920
McIver, Miss Euphemia, M.Sc., Higher Elementary School, Rochester	1936
McLennan, Assoc. Prof. Ethel, D.Sc., University, Carlton, N.3 ..	1915
Macpherson, Miss J. Hope, National Museum, Melbourne .	1940
Melhuish, T. D'A., M.Sc., Mt. Frome Lime Co., Burrow-road, St. Peters, Sydney	1919
Moore, F. E., O.B.E., Chief Electrical Engineer's Branch, P.M.G.'s Department, Treasury Gardens, East Melbourne, C.2	1920
Morris, P. F., National Herbarium, South Yarra, S.E.1	1922
Newman, B. W., B.Sc., Meteorological Bureau, Sydney	1927
Nye, E. E., College of Pharmacy, 360 Swanston-street, Melbourne, C.1	1932
Nye, Rev. Edward, B.A., Wesley College, St. Kilda-road, Prahran, S.1	1934
Oke, C., 34 Bourke-street, Melbourne, C.1	1922
Osborne, N., c/o Australasian Petroleum Co., Port Moresby ..	1930
Paterson, Miss Helen, "The Wilderness," Warrandyte	1933
Petersen, Miss K., B.Sc., 56 Berkeley-street, Hawthorn, E.2 ..	1919
Prentice, H. J., B.Sc., 218 Esplanade West, Port Melbourne, S.C.1	1936
Pretty, R. B., M.Sc., Technical School, Wonthaggi, Vic.	1922
Raff, Miss J. W., M.Sc., F.R.E.S., University, Carlton, N.3 ..	1910
Rayment, Tarlton, Bath-street, Sandringham, S.8	1929
Richardson, Sidney C., 2 Geelong-road, Footscray, W.11	1923
Rosenthal, Newman H., B.A., B.Sc., 10 Oulton-street, Caulfield, S.E.7	1921
Rothberg, M., B.Agr.Sc., 1094 Lygon-street, N.4	1937

Sayce, E. L., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3 1924

Scott, T. R., M.Sc., B.Ed., 27 Currajong-avenue, Camberwell, E.6 .. 1934

Shaw, Dr. C. Gordon, 57 Clendon-road, Toorak, S.E.2 1931

Sherrard, Mrs. H. M., M.Sc., 43 Robertson-road, Centennial Park, N.S.W. 1918

Stach, L. W., M.Sc., c/o Australasian Petroleum Co., Port Moresby, Papua 1932

Sutherland, Miss Jean L., M.Sc., Presbyterian Girls School, Glen Osmond, Adelaide, S.A. 1934

Thomas, L. A., B.Sc., c/o Council for Scientific and Industrial Research, Stanthorpe, Queensland 1930

Traill, J. C., B.A., B.C.E., 630 St. Kilda-road, Melbourne, S.C.3 .. 1903

Trüdinger, W., 27 Gerald-street, Murrumbeena, S.E.9 1918

Tubb, J. A., M.Sc., Fisheries Section, C.S.I.R., Cronulla, N.S.W. .. 1936

Vasey, A. J., B.Agr.Sc., "Westaways," Werribee 1937

Vasey, G. H., B.C.E., University, Carlton, N.3 1936

Wilcock, A. A., B.Sc., B.Ed., 294 The Avenue, Parkville, N.2 .. 1934

Wilson, F. E., F.E.S., 22 Ferncroft-avenue, E. Malvern, S.E.5 .. 1921

Wilson, Major H. W., O.B.E., M.C., C. de G., M.Sc., 630 Inkerman-road, Caulfield, S.E.7 1923

Wood, E. J. F., M.Sc., B.A., Fisheries Section, C.S.I.R., Cronulla, N.S.W. 1935

Wood, Assoc. Prof. G. L., M.A., Litt. D., University, Carlton, N.3 .. 1933

Woodburn, Mrs. Fenton, 21 Bayview-crescent, Black Rock, S.9 .. 1930

Wunderly, J., D.D.Sc. (Melb.), 2 Collins-street, Melbourne, C.1 .. 1937

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